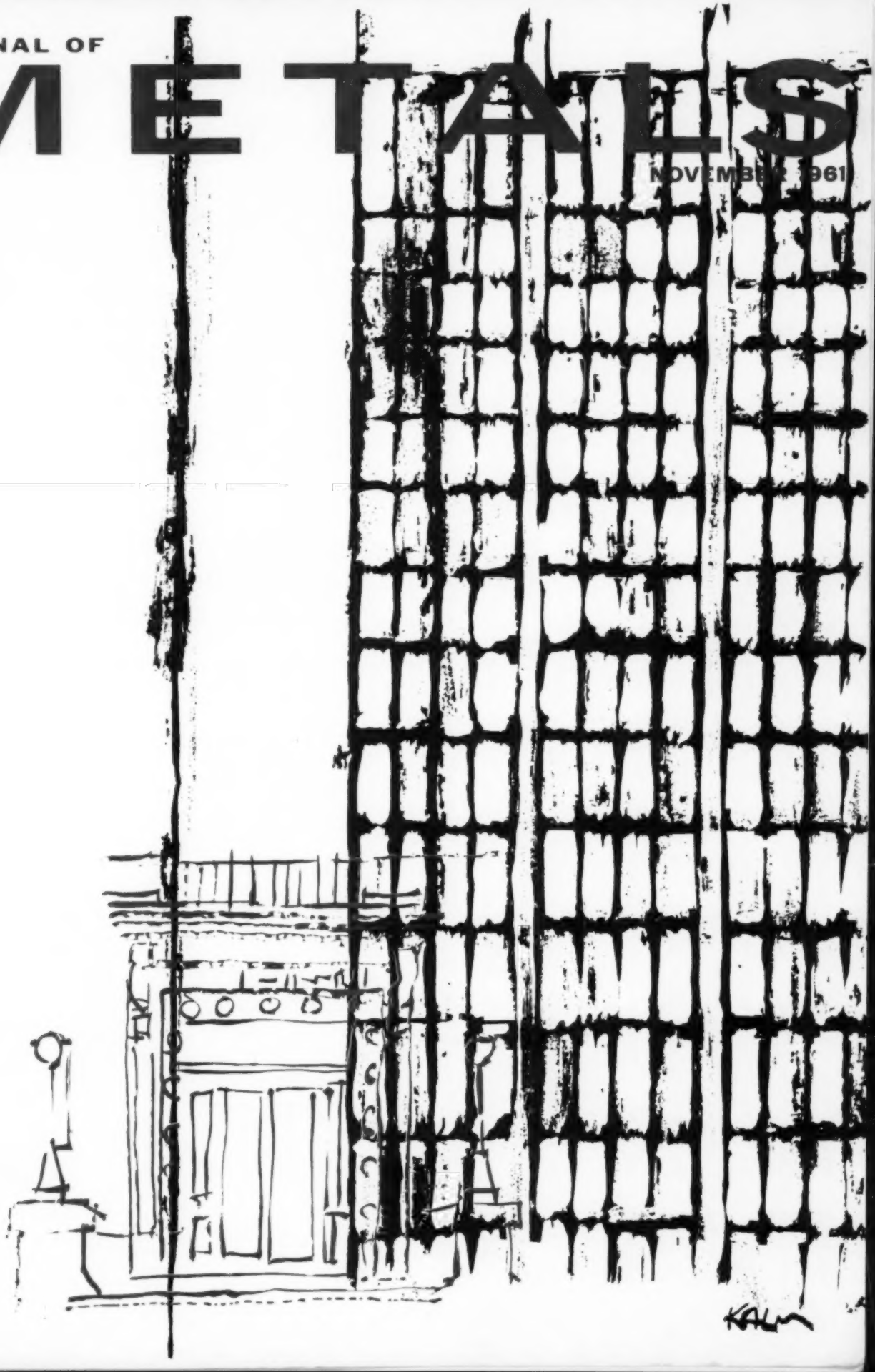
JOURNAL OF

METALS

NOVEMBER 1961



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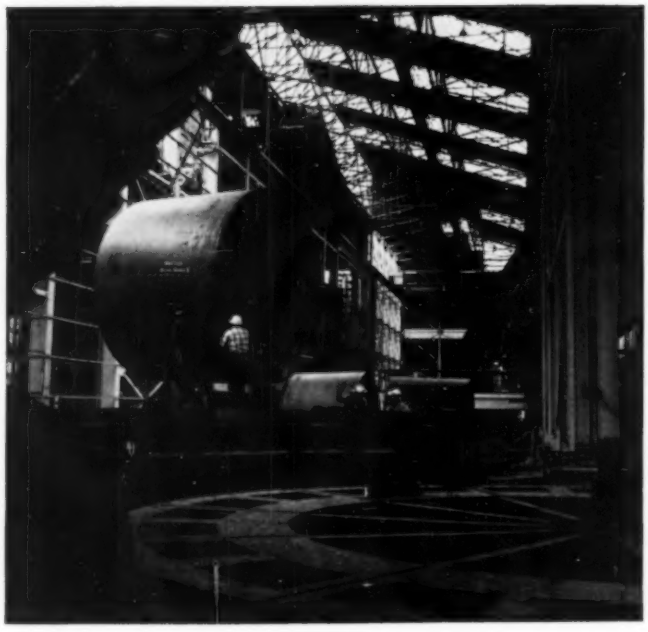

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JOURNAL OF

METALS

Vol. 13, No. 11
November, 1961

COVER: New York artist, Chet Kalm, has produced this month's cover depicting the move of AIME headquarters from 39th Street to the sparkling new United Engineering Center on the United Nations Plaza.

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personnel

• These items are listings of the Engineering Societies Personnel Service, Inc. This Service, which cooperates with the societies of Civil, Electrical, Chemical Mechanical, Mining, Metallurgical, and Petroleum Engineers, is available to all engineers, members and non-members, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 60% of the first month's salary if a non-member, 50% if a member. Also, that you will agree to sign our placement fee arrangement which will be mailed to you immediately after receiving your application. In sending applications be sure to list the key and job number.
• When making application for a position, include eight cents in stamps for forwarding application to the employer and for returning, when possible.

—MEN AVAILABLE—

Staff Assistant, B.S., M.S., Met. Eng., age 40. Chief metallurgist, 15 years, melting and processing alloy, tool, stainless steels. Proven administrative ability, including operations, cost studies, production planning, research, and quality control. Will relocate. M-263

Metallurgical Engineer, B.S., Met., Eng., age 24. Fifteen months with non-ferrous smelter; wide range research and development work, alloying procedures, fluxing, metal atomizing, standardization of X-ray spectrograph. Prefer Chicago, will relocate. M-2286-Chicago

Sales or General Manager, B.S., Elec. Eng., age 48. Electrical equipment sales to chemical, auto, paper, and distributor promotion, also metalworking, machine tool, and OEM; mechanical equipment to chemicals, cement, and steel industry. Prefer Detroit. M-2287-Chicago

Metallurgist-Metals, Electronics: metallurgy background, 27. $8500. Prefer San Francisco Bay Area. Home: California. Five years refractory metals research, high vacuum metallurgy, sand and precision casting. Se-1448

Estimator-Steel Fabricators: 44. $700. San Francisco or Peninsula. Home: California. Twenty years estimator, cost analysis, shape in fabricated steel. Se-1506

Mine, Mill-Metallurgist: Mine, Met. Eng. (England), Reg. P.E. Africa. 55. $600. Prefer foreign. Home: California. Eleven years mine, mill, metallurgy. Design, construction, gravity concentration mill for beneficiation of chromite and mill for cyanidation, flotation, concentration overseas. Se-1303

—POSITIONS OPEN—

Engineers. (a) Leader, Physical Metallurgy, degree in metallurgy, M.S. or Ph.D. preferred, with several years advanced level experience, to lead research efforts on high-temperature, high-strength materials, furthering fundamental understanding of the physical metallurgy of nickel, cobalt, iron, and titanium-base alloys. (b) Metallurgical Application Engineer, minimum B.S. in metallurgy, with two to five years experience, to develop specifications and processing requirements for materials used in advanced rocket engine nozzle and auxiliary power sources for space and missile application; to oversee materials evaluation tests, write reports and consult on special problems. Ohio. W796

General Shift Foreman, Smelter, B.S. in metallurgical engineering or related field, with four years smelting experience including operation of roasters, reverberatory furnaces and converters. Operating supervisory, metallurgical engineering, or maintenance experience acceptable. Employment on contract basis in multiples of two years. Home leave vacation of two months at end of two year contract. Transportation paid both ways and salary while traveling. Apply by letter giving complete details and references. South America. F785

Metallurgical Engineer with several years experience in laboratory functions associated with ferrous and high quality steel metallurgy, for control of metallurgical processes through checking heat treating and other processes of a metallurgical nature. Metallography of annealed and heat treated structures. Control of raw material by assuring conformance to existing material specifications. Apply by letter, including salary requirements. Northern Ohio. W752

Physical Chemist or Metallurgist, preferably with M.S. in electro or inorganic chemistry, for research project. $7000-$10,000 year. Long Island, N. Y. W749

Sales Engineer, good metals trader. Must be experienced in non-ferrous metals, ores, and rare metals. $10,000 year or better. Some traveling. Headquarters, New York City. W735

Staff Metallurgical Engineer with at least five years experience covering design and layout of copper ore handling and metallurgical processing equipment. Salary open. Near East. F481(b)

Process Engineer, M.S., Met. Eng., over 35, for consulting, feasibility of economic studies and process design for an engineering and construction company. Desire eight or more years experience, non-ferrous, pilot plant through operations. $9600-$12,000. Employer will pay fee. California. C8837

Production-Melt Shop: $10-12,000, Canada. Metallurgist to 50. Ten years steel shop superintendent. Must have worked in rim steels and semi-killed for manufacture of skelp and plate. Employer will pay fee. Sj-6475

Metallurgist-Extractive: Salary open, Los Angeles Area, any age, M.S. preferred. Eight years nonferrous metallurgy, pilot plant design and operations, feasibility and economic analysis, consulting, and process design. For an engineer-builder. Sj-6493

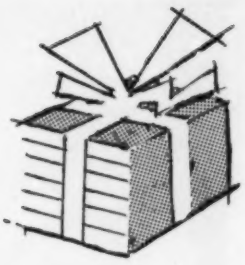
Teacher, Research-Mineral: $7000-8400, in the West M.S., Ph.D., 25-40. To teach, conduct research. Know ceramics, metallurgy, chemical engineering, physical chemistry, or materials science. Emphasis on basic research. Sj-6434

Sales-Gases and Apparatus: $500-550, in San Francisco Peninsula, graduate, recent graduate, or some experience. Able to handle sales engineering problems related to the use of industrial gases and apparatus for welding and other industrial, process, chemical or other plant uses. Covers a broad field of industrial applications of a variety of gases and equipage for their use. For a district office of a national organization. Developed territories. Sj-6392

Metallurgist, Quality Control-Mill: $550 up, West U.S., Metallurgist, Chemist. Consider recent graduate, prefer some experience. Assist in control process techniques, procedures, quality control, chemical analysis on hard metal carbides. For a processing firm. Sj-6551

Address replies for positions to the nearest local office of the Engineering Societies Personnel Service, Inc., *not* to the JOURNAL OF METALS. Offices are located at 29 E. Madison St., Chicago 1, Ill. . . . 57 Post St., San Francisco, Calif. . . . and 8 W. 40th St., New York 18, N. Y.

A weekly bulletin of engineering positions open is available to AIME members at a subscription rate of $4.50 per quarter or $14 per annum; $4.50 per quarter or $14 per annum for nonmembers, payable in advance. Local offices of the Personnel Service are at 8 W. 40th St., New York 18; 57 Post St., San Francisco; and 29 E. Madison St., Chicago 1.



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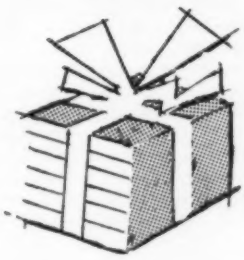

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SUBJECT:

aluminum

at work in steel

Aluminum serves three purposes in ferrous metallurgy. It is (1) an alloying element, (2) a deoxidizer, (3) a grain-refining agent.

Aluminum an Aid in Creating Wear-resistant Steels

As an alloy of iron, aluminum has been put to good use in heat-resisting alloys and permanent magnet alloys. The largest single use, however, is in nitriding steels. The nitriding process is one in which aluminum bearing steels are held for a long time in ammonia at an elevated temperature. The precipitation hardening which occurs with the dispersion of aluminum nitrides at the surface, gives these steels a hard, wear-resistant case.

Aluminum a Versatile Control from Heat to Ingot

As a deoxidizing agent, aluminum is used in various ways in steel. In rim, capped or semi-killed steels, aluminum can be used to partially deoxidize heats in the ladle, thus limiting the evolution of gases, or it can be used to stop reactions in the ingot. In the latter case, the degree of usage is varied. Some ingots are chemically capped by an aluminum addition. Other ingots may be aluminum treated only when it is necessary to control bleeding. Even when steels are fully killed with silicon, aluminum is sometimes added in the ladle to insure complete deoxidation.

Aluminum Refines Grain, Reduces Strain Sensitivity

Steels which require aluminum for grain control fall into two main categories: (1) steels in which aluminum is added in conjunction with another deoxidizer, generally silicon; (2) steels in which aluminum is the only deoxidizer used.

In the first instance, only enough aluminum is added to refine the grain and obtain the desired physical properties of a fine-grain steel.

The second usage stems from the marked effect which aluminum has in reducing the strain sensitivity and strain aging of low carbon steels. As might be expected, the primary use for these steels is in sheet applications where the metal undergoes severe deformation.

Foote Manganese-Aluminum Alloys Produce Better Surface, Cleaner Steels

Foote offers a series of manganese-aluminum alloys for steel-making. These alloys provide a high density means of adding aluminum to steel. In the alloyed form, greater dispersion of aluminum is possible. An added bonus is that this reduces the tendency towards "tapering off" of aluminum analysis on the last ingots. Better surface and cleaner steels are reported with use of Foote alloys.

For further information on Foote manganese-aluminum alloys, write Technical Literature Department, Foote Mineral Company, 481 Eighteen West Chelten Ave., Phila. 44, Pa.

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education

Case Institute of Technology

Alan H. Cottrell, Goldsmiths' Professor of Metallurgy and Fellow of Christ's College, University of Cambridge, was the principal speaker at the Charles M. White Dedication Lectures for the new metallurgy building at Case Institute of Technology. Dedication of the new building took place October 10.

Dr. Cottrell gave the first of two technical lectures on the mechanics of fracture on Monday, October 9, in Case's Strosacker Auditorium. The second technical lecture was on Tuesday. That evening Dr. Cottrell also delivered a lecture on today's trends in materials research.

Dedication of the new metallurgy building on Tuesday afternoon was preceded by an informal open house. The $2.7 million, six-story building contains special facilities which allow for the study of materials under a complete range of environmental factors including temperatures, pressures, and load conditions. There are also laboratories for the study of principles of processing the new materials required for use in the space and nuclear ages.

The new building is named for Charles M. White, a Case Trustee and former president and chairman of the board of Republic Steel Corp.

Carnegie Institute of Technology

A new Philips EM-200 electron microscope, capable of a total ultimate magnification of approximately 2 million has been acquired by the department of metallurgical engineering at Carnegie Institute of Technology.

The microscope, which is equipped with a special metallurgical objective lens of the immersion type, permits a wide variety of experiments to be performed on a specimen in the microscope which were not previously possible. It is capable of distinguishing objects or particles of a few atomic diameters. Specimens measuring 1/1,000,000 of an inch in thickness are used in the testing.

Present studies on the microscope have two main objectives: an understanding of the factors involved in the strength of materials, and a microscopic study of the nature of fatigue failures. The microscope will also be used for graduate study in the department of metallurgical engineering.

books ANNOUNCEMENTS AND REVIEWS

Books that are marked (•) may be ordered through AIME. Address Irene K. Sharp, AIME Book Dept., 345 E. 47 St., New York 17, N. Y. A discount is given whenever it is possible.

Wiley, Interscience Merge

John Wiley & Sons Inc. and Interscience Publishers Inc. have merged. Operating under the name of John Wiley & Sons Inc., the publishing house will be devoted entirely to the production of books and journals in the various fields of natural and behavioral sciences, technology, and engineering.

Interscience has been the publisher of The Metallurgical Society's Conference Series of books, which contain proceedings of various conferences sponsored by the society. The Interscience publishing program will continue as a distinct Wiley division.

All operations of the two companies will be integrated in the Wiley Building, 440 Park Ave. South, New York 16, N. Y.

Aluminum

History of the Science, Technology, and Industrial Development of Aluminum, Part I, The Past (1890-1945) —in French—by L. Ferrand, published by Humbert & Fils, France, 644 pp., regular edition, $20.50; deluxe edition, $25.50; 1960. *Reviewed by F. R. Morral, of Battelle Memorial Institute.* •

This volume is the first of a trilogy by a past director of the important French producer, Pechiney. Volume 2 will deal with *The Present 1945-1960* in approximately 588 pages. The author is now preparing the third volume with the intriguing title, *The Future.*

Volume I has received the Prize Binoux of 1959 (for history and philosophy of science) of the French Academy of Science. The book is divided into four chapters which present, with extensive documentation the following periods of the life of aluminum: 1) The origin (1800-1855); 2) Birth (1855-1885); 3) Childhood (1885-1920); and 4) Adolescence (1920-1945).

The author, associated for a long time with this industry, traces with understanding and impartiality the history of men, processes, and developments of the new industry. In many instances, he has personal opinions which help make more interesting the controversial sections. Incidentally, Mr. Ferrand points out that in America, we have not given proper credit to C. S. Bradley for his work. He applied for a patent on February 23, 1883, while C. M. Hall's was not requested until July 9, 1886. Paul Heroult's was requested April 23, 1886. Furthermore, the process first patented by Hall was not practical.

In Chapter IV, a detailed discussion is given with extensive summary from papers from the literature on the thermodynamics and physical chemistry of electrolytic baths, mechanisms of electrolytic reactions, and theories of electrolysis. A section is devoted to abnormal phenomena, such as the *Anode Effect*, and the opinions of German, Russian, and other investigators.

Under the title, History of Technology, are given furnace developments (Soderberg anodes, etc.), operation, and properties of the metal (commercial and extra pure). Industrial developments of the major producing countries and of the smaller ones (total of 18 countries) up to 1945 are reviewed.

This expert author comes to the conclusion that by 1945, many questions had been raised, and the answers were, in most cases, controversial, and the subject of much thought and research in later years. This is the subject matter for Volume 2.

This trilogy, if further volumes follow the pattern of this first one, should become the most complete and up-to-date study of the scientific, technological, and patent literature of the interesting industry, aluminum.

Platinum

A History of Platinum by Donald McDonald, Johnson, Matthey & Co., Ltd., London, available from J. Bishop & Co., Malvern, Pa., 254 pp., $5.50, 1960. *Reviewed by Henry J. Albert, Engelhard Industries, Inc.* •

The past 30 years have witnessed a remarkable change in the use of the platinum group metals. At the earlier time, a high proportion of these metals was used in jewelry and decorative applications with a much smaller amount being used industrially. This situation has now been reversed, however, and by far the greatest use of the platinum metals is in industrial and commercial applications. This reversal has come about as technological changes in processes have imposed increasingly difficult conditions on the materials being used. The wide diversity of applications include melting equipment in the glass industry, corrosion-resistant vessels and catalytic agents in the chemical and petroleum industries, and contacts and special wire in the electrical industry. In addition, there are a host of smaller applications including the dental, medical, and decorative uses.

In *A History of Platinum*, Donald McDonald has traced this history from the discovery of platinum through the early work on purification and working of platinum and on into the commercial history of platinum up to 1890. This type of history is always interesting to the practicing metallurgist, combining as it does the scientific, technological, and commercial history into a unified story. It is especially interesting to note the remarkable similarity between the history of platinum and the more recent history of a metal such as titanium which was developed on a much more compressed time scale but had comparable problems of refining, melting, and working. Mr. McDonald's account of platinum's history is an extremely lucid one and shows the results of what must have been a very diligent search of the literature and archives relating to this subject. His long association with and free access to the records of Johnson, Matthey & Co., Ltd. was, of course, of great value. It is certainly to be hoped that Mr. McDonald will be able to extend his history from 1890 to the present. Prior to 1890, the history of platinum is exclusively European. After 1890, the American contribution to the development of platinum began.

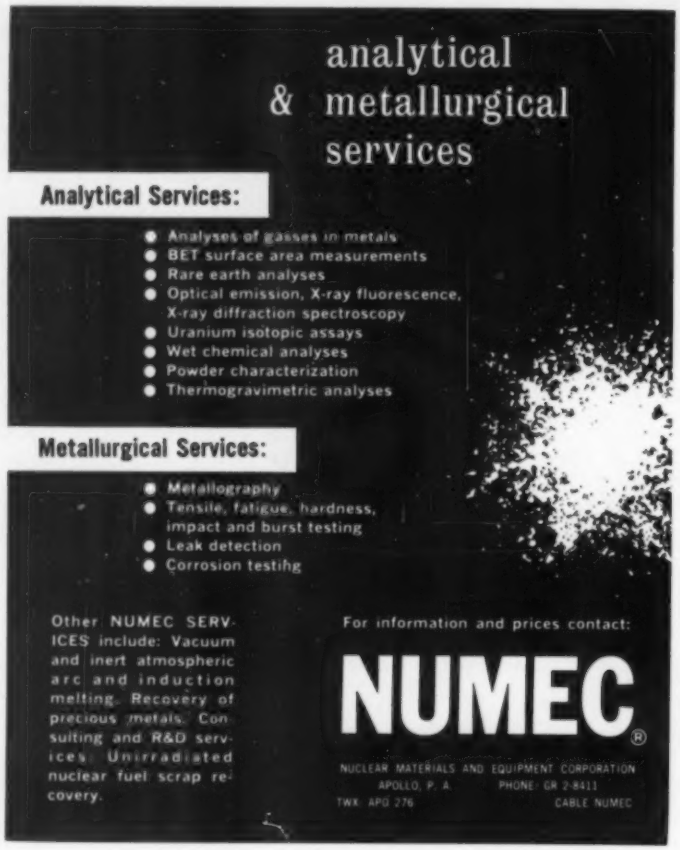
• • •

Elevated Temperature Properties of Aluminum and Magnesium Alloys—STP 291, published by the American Society for Testing Materials, 314 pp., $7.00, 1961. •

This publication summarizes elevated temperature, tensile, and creep rupture properties of current commercially-established aluminum and magnesium alloys which would normally be used at elevated temperatures. The material included in this compilation constitutes elevated temperature data of the type used in determining allowable stresses for the Unfired Pressure Vessel Code of the ASME Boiler Code Committee. Effort has been made to cover those alloys used in the aircraft industry for elevated temperature applications. Both wrought and cast alloys are covered in various forms; some data are given for alclad aluminum alloys.

Copies of the book may be ordered

(Continued on next page)



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Books

(Continued from page 773)

from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

Guide to Metallurgical Information: SLA Bibliography No. 3, edited by Elizabeth W. Tapia, published by Special Libraries Assoc., 96 pp., $4.00, 1961. •

This bibliography describes more than 600 books, journals, and other information sources in the field of metallurgy. The coverage includes societies, trade associations, research institutes, government agencies, and technical services concerned with metallurgy, as well as books, periodicals, microforms, translations, and theses. The scope is world-wide, and reference sources published within the last 20 years are emphasized, although some older material is listed. There are three indexes—Author and Agency, Book and Journal Title, and Subject.

Copies of the bibliography may be ordered from Special Libraries Assoc., 31 East 10th Street, New York 3, N. Y.

Technical Translations

Several translations of technical papers which may be of interest to metallurgists have recently been issued by Henry Brutcher, Technical Translations, P.O. Box 157, Altadena, Calif. Among the papers are:

New [Polish] Equipment for Degassing of Steel by I. Mydlarz, from Problemy Projektowe, 1960, $2.50, 500 words, Order No. 5177. This is a brief extract of a Polish paper describing two vacuum degassing plants designed according to the Bochumer-Verein principle.

Reactions in Rotary Steelmaking Vessels with Oxygen Top Blowing, Part I, by Hardt, Vocke, and Schenck from Stahl Und Eisen 1961, $15.75, 6200 words, Order No. 5088. This paper discusses the development of a refining process in rotary furnaces that is applicable to any kind of pig iron, gives a heat time shorter than in basic bessemer converting, and produces low-phosphorus, high-carbon steels comparable to basic open hearth grades without recourse to recarburizing additions, entirely by virtue of the vigorous additional mechanical motion of the bath induced by a non-circular, instead of a circular-section rotor.

On the Metallurgy of the Phoenix Lancing Process by Schürmann, Aschendorff, Höfges, and Köhler

(Continued on page 776)

METALGRAMS

UNION CARBIDE METALS

. . . news of "Electromet" ferroalloys and metals

NOVEMBER 1961

COLUMBIUM -- AN OLD ELEMENT WITH NEW USES -- Although columbium was discovered by Hatchett in 1801, it did not find any metallurgical uses until the 1930's. Then, Union Carbide Metals found that columbium prevented intergranular corrosion of 18-8 stainless steels, allowing welding. Other UCM findings: (1) Columbium improved the strength and toughness of plain-carbon and low-alloy high-strength steels; (2) Columbium reduced air hardening in plain-chromium stainless steels; and (3) Columbium increased the strength of high-alloy compositions at high temperatures. These applications find wide commercial use today.

* * *

COLUMBIUM STEELS CAPTURE HEADLINES -- Recently, a lot of interest has been shown in carbon steels containing a pinch of columbium. Up to 0.03 per cent improves strength and weldability with only a minor loss in ductility. At a price only slightly more than plain-carbon grades, the high-strength of these steels offers cost savings by permitting designers to use lighter sections. Today, columbium steels are being used in trucks and trailers, earth-moving and construction equipment, oxygen cylinders, and line pipe.

* * *

GROWTH PROBLEMS -- Columbium steels are having growing pains, though. Of some concern has been the transition temperature from ductile-to-brittle fracture. Although satisfactory low-temperature impact properties have been obtained in plate thicknesses up to 3-8 in., the transition temperature of heavier plate sections has increased. Research has shown that higher manganese contents, water quenching off the hot mill, or normalizing can improve heavier section impacts. For more information, write for the article, "Columbium in Carbon Steels," in the Fall 1961 issue of UNION CARBIDE METALS REVIEW.

* * *

FERROCOLUMBIUM AND COLUMBIUM METAL -- Union Carbide Metals has been producing high-quality ferrocolumbium and ferrotantalum-columbium for steel and high-temperature alloys since 1935. Now, UCM also offers electron-beam-melted ingots of columbium metal -- the purest columbium available. Columbium metal and columbium-base alloys have many potential uses. Their superior strength at high temperatures suggests many aircraft and space-vehicle applications. Their resistance to molten salts opens up chemical-equipment uses. Columbium's moderate neutron cross-section allows use in nuclear-reactor structures. Alloys of columbium are also being widely tested as superconductive materials. For more information, write for F-20,133 on ferrocolumbium, data sheet Cb-1 on columbium metal, and the article, "Mill Products Multiply," in the Fall 1961 issue of UNION CARBIDE METALS REVIEW.

* * *

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BOOKS

(Continued from page 774)

from Stahl Und Eisen, 1961, $18.75, 7500 words, Order No. 5089. This is a study of the Phoenix-Lancing (PL) process for its particular metallurgy, compared with that of the basic bessemer process.

Continuous Blowing of Hot Metal in Runner with Oxygen by Fuklev, from Izvest. Vuz—Chern. Met., 1960, $6.85, 2700 words, Order No. 4926. This paper discusses the promise of continuous oxygen blowing of liquid pig irons in runners, a practice in line with other continuous metallurgical processes, and a more complete suppression of brown fumes.

Basic Oxygen (LD) Steel in Wire Manufacture by Fogy and Kramer, from Berg- Und Huttenmannische Monatshefte, 1960, $13.80, 4900 words, Order No. 5050. This article discusses the merits of basic oxygen steel for wire mills, compared with open-hearth, electric, and other steels. Also discussed are the advantages of LD steel wire in the manufacture of various wire products.

Kinetics of Direct Oxidation of Impurities in Liquid Iron by Filippov and Martynov, from Izvest. Vuz—Chern Met., 1961, $7.25, 2700 words, Order No. 5134. This is a laboratory study of rates of oxidation of various elements dissolved in liquid iron, at different rates of feed of gaseous oxidizing agents, to obtain a more complete understanding of the mechanism of direct oxidation of the components of a melt.

Molybdenum brochure

Schwarzkopf Development Corp. has issued *Molybdenum*, a 57-page brochure on molybdenum metal which describes the properties of the metal, its availability in mill supply forms and various fabricated shapes, and its present applications in industry. There are 45 tables and graphs of properties and specifications and 16 pictures sketches of products in actual applications. Included in the text is a section on how to machine and work the metal to finished form. The brochure includes a table of contents and a bibliography.

Copies may be obtained free from Schwarzkopf Development Corp., 595 Madison Ave., New York 22, N. Y.

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Recently Accepted TRANSACTIONS Papers

Chlorination of Rutile, by Arne Bergholm (EMD)

Horizontal Induction Zone Melting of Refractory Metals and Semiconductor Materials, by A. Berghezan and E. Bull Simonsen (EMD)

Thermal Expansion of Ti and Some Ti-O Alloys, by R. J. Wasilewski (IMD)

The Effect of Heat Treatment and Microstructure on Carbon Strain Aging in Low Carbon Steels, by J. F. Butler (IMD)

Identification and Stability of Bn in Boron Low Carbon Steels, by J. F. Butler (IMD)

Direct Observations on the Annealing of a Silicon-Iron Crystal in the Electron Microscope, by Hsun Hu (IMD)

Kinetics of Reduction of Magnetite to Iron and Wustite in Hydrogen-Water Vapor Mixtures, by Jean M. Quets, Milton E. Wadsworth, and John R. Lewis (ISD)

Effects of Variations in Carbon Content, Heat Treatment, and Mechanical Working on the Stress-Rupture Properties of a Liquid-Phase-Sintered High-Temperature Alloy, by Philip A. Clarkin, John W. Weeton, and Paul F. Sikora (IMD)

The Phase Structure of Inconel 718 and 702 Alloys, by M. Kaufman and A. E. Palty (IMD)

Effect of Ternary Elements on the Eutectoid Transformation in Aluminum Bronze, by T. V. Philip and David J. Mack (IMD)

Deformation and Fracture Characteristics of Fe-S, Fe-S-O, and Fe-S-Mn Alloys at High Strain Rates and Temperatures, by S. Y. Ogawa, T. B. King, and N. J. Grant (ISD)

Fluid Flow Control During Solidification Part II: Programmed Solute Distribution, by W. C. Johnston and W. A. Tiller (IMD)

The Solubility and Precipitation of Nitrides in α-Iron Containing Manganese, by J. F. Enrietto (IMD)

Crystallography of Equilibrium Phase Interfaces in Al-$CuAl_2$ Eutectic Alloys, by R. W. Kraft (IMD)

The Sintering and Strength of Coated and Co-Reduced Nickel Tungsten Powder, by J. H. Brophy, H. W. Hayden, and J. Wulff (IMD)

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C-Cr-Fe Liquidus Surface, by N. R. Griffing, W. D. Forgeng, and G. W. Healy (ISD)

Effect of Superimposed Static Tension on the Fatigue Process in Copper Subjected to Alternating Torsion, by W. A. Wood and H. M. Bendler (IMD)

Transfer of Sulphur or Oxygen from a Low to a High Chemical Potential through an Ionic Membrane, by E. T. Turkdogan and P. Grieveson (ISD)

The Use of Vanadium Nitride Inclusions for the Development of Cube-On-Edge Texture in 3 pct Silicon-Iron, by H. C. Fiedler (IMD)

Shear Textures in Copper, Brass, Aluminum, Iron, and Zirconium, by Robin O. Williams (IMD)

Precipitation of Zirconium Hydride in Alpha Zirconium Crystals, by D. G. Westlake and E. S. Fisher (IMD)

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Gaseous Reduction of Oxygen-Containing Copper, by Leonard Klein (EMD)

The Constitution Diagram Tungsten-Hafnium, by Bill C. Giessen, Irmgard Rump, and Nicholas J. Grant (IMD)

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Effect of Cold Work on Copper-Rich Copper-Iron Alloys, by A. Boltax (IMD)

Soderberg Anode Carbon in Cells for Electrolytic Production of Aluminum, by Olav Bowitz and Ove Sandberg (EMD)

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letters to the editor

LD Kinetics

Professor Philbrook has prepared a fine analysis of LD steelmaking (JOURNAL OF METALS, Sept., pp., 613–620) that will be of considerable help to students and to steelmakers.

It may not be possible actually to see what takes place in the vessel because of the flame and fume, but our common sense and good judgment of what we know about chemistry at high temperatures and fluid mechanics should help us in analyzing the system. A few comments on bath circulation may help to illustrate this.

A jet of non-absorbed gas which impinges vertically downward on a bath of water will cause the water to circulate with the flow upward at the center, across the upper surface, and down the walls. This has been shown by a number of investigators which include Hammer, Kootz, and Sittard (Stahl U Eisen, vol. 77, no. 19, 1957, p. 1303), and any boy playing at the tire-repair station in a local garage.

It is interesting to consider what happens to the bath in an LD vessel during the carbon boil when most of the oxygen is being used to remove carbon (directly or indirectly) from the metal bath. Assume a blowing rate of 3500 cfm for a 50 ton heat. This results in an actual volume of approximately 800 cu ft of CO forming per sec; a volume that is 3.5 times that of the metal in the vessel. The nearest comparison is a rimming ingot. If we assume a 25 ton ingot that forms a 4 in. rim in 16 min, it will evolve approximately 3 cu ft of CO per sec early (1 min) in the rimming process. The contrast is striking, and one need only visualize what the bath in the vessel is doing if he were to imagine a hundred fold increase in the evolution in the rimming ingot.

Thus, if the vessel walls are relatively cool and/or if scrap is still present, the motion of the metal due to gas evolution might well overpower the effect of the jet action.

John F. Elliott
Associate Professor
of Metallurgy
Massachusetts Institute
of Technology

Reply by W. O. Philbrook

There is no basic disagreement between Dr. Elliott's comments and statements in the article in the first two paragraphs under the heading *The Carbon Boil*, pp. 617-618 (Sept. JOURNAL OF METALS). Numerical values in the article appear more conservative because they were calculated with an allowance for ferrostatic head and mean temperature of the metal early in the boil, whereas Dr. Elliott's calculation is for gas leaving the metal at about 3000°F. In my view, the physical similarity to a rimming steel ingot needs to be modified to describe conditions in the basic oxygen furnace. The much larger volume of escaping gas seems to require rising currents over a much larger fraction of the cross-section, and this is favored by the smaller height to diameter ratio in the furnace in comparison with a rimming ingot.

W. O. Philbrook
Carnegie Institute of Technology

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A Correction . . .

And an apology to the hard-working gentlemen of the 1961 Blast Furnace, Coke Oven, and Raw Materials Conference, which was held in Philadelphia April 10-12. In the October issue of JOURNAL OF METALS, we printed the excellent paper, *Blast Furnace Fuel Oil Injection* by W. R. Rumbough, which had been presented at that meeting. However, we incorrectly attributed the paper to another conference.

Our apologies to all concerned.

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scannings

The Long Hot Summer, The Move, And Tragedy

The weather prophets had predicted it. "Yes," said they, "a cold winter is followed by a hot summer," but they also say that a cold winter follows a hot summer; so, it is pretty difficult to win one way or the other. And, in actual fact, New York weather generally seems bent on a pattern of extremes.

But this summer was even worse than predicted, and one 90° day followed another as record after record was shattered. Nevertheless, we remained at our posts defending the 39th Street bastion known as the Engineering Societies Building. Our spirits were buoyed up with thoughts of lush new air-conditioned quarters being prepared on the East Side. But sitting in our pools of sweat, wiping the soot from our brows, and climbing over the ever-present hat boxes on *millinery row*, it all seemed something like the classical mirage of the Sahara oasis.

Summer was drawing to a close as the fans whirred ever faster. At long last the great day was upon us, and our soot-covered implements were safely placed in boxes destined to be delivered to the *promised land*. Somehow it was hard to believe that the following Tuesday—Monday was Labor Day—would find us in sunlit, clean, air-conditioned quarters. We felt something like Hottentots about to move into a Beverly Hills mansion.

Tuesday, September 5, and there it was—spanking new and glistening in the sun. We filled our lungs with purified air as we entered the lobby and rose to our 13th floor palace. There was the East River and to the north the fabled penthouses of Sutton Place. We were even higher than they. We were almost like children playing with a new toy as we went back and forth to our new offices during the first week of September. But time drifted into the second week, and we gradually began to realize that the dream was reality, and we were living in it.

• • •

But there was a dark cloud on the horizon. And we watched the limousines of diplomats coming and going at the United Nations Headquarters across the street, not realizing that tragedy was was about to fall on the house of our new neighbors.

Monday morning September 18—the radio had an ominous report of a plane overdue at a place called Ndola in Northern Rhodesia; the plane was carrying the UN Secretary General. We hoped that the worst hadn't happened, but as we watched the United Nations' flag being brought to half mast later that morning, we realized that it had happened. Our neighbor was dead.

Long before moving to the United Nations Plaza, Dag Hammarskjold had become an ideal to many of us, including the writer. Perhaps the greatest tribute to the man may have been contained in a New York Times' article that day:

"Not long ago Mr. Hammarskjold was asked if he could sum up his attitude to the organization that he had come to symbolize to much of the world. He paused a moment, then recalled a line from Shelley's *Prometheus Unbound*. 'One should', he said 'hope 'til hope creates from its own wreck the thing it contemplates.' ". **FWS**

High-Purity Electrolytic Chromium

Discussion of an article of the same title by M. J. Ferrante et al which appeared in the November 1960 issue of JOURNAL OF METALS.

by J. J. Dale and L. H. Esmore,
Defence Standards Laboratories,
Maribyrnong, Victoria, Australia

Experience over several years in the production of high-purity electrolytic chromium—mainly by the sulfate catalyzed process—prompts us to offer the following comments on the paper by Ferrante et al.[1]

While there is no doubt that the fluoride catalyst process is more efficient than the sulfate catalyzed process, the following points detract from its usefulness for the steady and economical production of relatively large quantities of pure metal:

1) The metal produced contains more impurities, notably oxygen and tin;
2) The solution cannot be purified by ion exchange;
3) The aluminum cathode cannot be used; hence a soluble cathode is required, and this entails much expense and inconvenience;
4) Excessive fuming and extreme corrosivity of the solution is encountered;
5) Excessive roughness and tree formation is found on cathodes with runs exceeding 15 to 20 hr;
6) Difficulties are found in maintaining solution composition; and
7) Falling efficiencies are noted with prolonged use of the bath.

Until these disadvantages are overcome, the sulfate catalyst would appear to be the better of the two processes. Its chief advantages are its relative simplicity and reliability which make it possible to operate the plant unattended over weekends by providing a suitable system of controls and safety devices. We use an aluminum cathode with a hemispherical end to give uniform current distribution. The open ended cathode used by Ferrante et al.[1] would tend to promote the excessive tree growth which seems to have been a feature of their experience with the sulfate catalyst. We have studied extensively the effects of process variables on efficiency and on the oxygen content of the metal obtained with this catalyst. Both temperature and bath composition need close control. A change of 5°C for example, can alter the oxygen content by a factor of three. Results of this work are to be published shortly.

With the fluoride catalyst, successive experimental runs in a 5 gal tank confirm Ryan's findings[2] that there is a progressive drop in efficiency despite the maintenance of the bath composition. The results given in the accompanying table show that even large additions of fluoride do not restore the efficiency to its initial value. For example, in runs 4 and 10 the amount of catalyst is the same but the efficiency has dropped by one-third in the latter run. Additions of HF do not raise the mean HF content in proportion, the loss during electrolysis being large and erratic (runs 8 and 9). Raising the trivalent content by reducing anode areas did not restore high efficiency. Lower trivalent contents are effects and not causes of lower efficiency.

It would be of interest to know if other workers are able to maintain high efficiency in successive overnight runs. It seems unlikely that the loss of fluoride through spray and evaporation can explain the effects noted. There are probably other ways in which the catalyst might also become ineffective, for example through formation of unfavorable complexes such as oxyfluorides.[3] In support of this explanation there are indications from Nuclear Magnetic Resonance (which we are trying out for rapid estimation of fluorine) that the fluorine in used electrolytes exists in two different molecular species. We propose to investigate this aspect in the near future.

Production of Pure Chromium Using Fluoride Catalyzed Electrolytes
Successive Test Runs at 500 amp per sq ft in 5 gal Tank

Run No.	Time, hr	Temp, °C	HF Addition, gpl	Bath Composition, gpl*			Efficiency, pct
				CrO_3	HF	Cr^{+++}	
1	4	96	0 (New Bath)	251	5.0	1.3	27
2	4	96	0.23	259	5.1	2.3	32
3	4	96	0.23	259	4.7	2.3	34
4	4	96	0.23	259	4.4	2.4	32
5	4.5	97	0.23	250	4.0	1.7	23
6	4	97	0.26	248	3.7	1.7	21
7	4	98	0	253	3.6	1.0	14
8	4	95	0.93	258	4.2	1.3	24
9	4	98	0.46	260	4.3	1.1	20
10	4	97	0.46	259	4.5	1.0	29

* Figures given are averages of concentrations before and after each run.

References

[1] M. J. Ferrante, P. C. Good, F. E. Block, and D. H. Yee: High-Purity Electrolytic Chromium, JOURNAL OF METALS, vol 12, no. 11, 1960, pp. 881-865.
[2] N. Ryan: Electrodeposition of High-Purity Chromium from Electrolytes Containing Fluoride or Fluosilicate, *J. Electrochem. Soc.*, vol. 107, 1960, p. 397.
[3] N. Ryan: Private communication.

REPLY

by M. J. Ferrante,
US Bureau of Mines

We were pleased to learn that the work of J. J. Dale and L. H. Esmore on chromic acid-fluoride electrolytes is in general agreement with our findings. Our work differs somewhat in that silicofluoride catalyzed electrolytes were used in addition to fluoride catalyzed electrolytes. Higher current efficiencies were obtained consistently with the silicofluoride catalyzed electrolytes.

In either case, our tests were confined to intervals of only 4 to 5 hr. It would be interesting to determine if the silicofluoride electrolyte would also be susceptible to aging upon prolonged use.

Although a cathode with a hemispherical end might maintain a more uniform current distribution, our problem with excessive dendrite formation occurred over the entire cathode surface rather than at the bottom. We feel this was due primarily to the high current density at which the sulfate catalyzed electrolytes were operated and might explain why Dale and Esmore did not share the same experience.

personals

Ralph David Barer, consulting engineer of Victoria, British Columbia, Canada, has received one of the ten International Awards of $1000, offered by the American Hot Dip Galvanizers Association in cooperation with the American Zinc Institute. Mr. Barer received the award for an idea for the substitution of forged and galvanized steel clamps for scaffold construction to retain the strength of steel, and eliminate the uncertainties of performance of lighter metals.

William F. Boyer has been named fabrication plant production superintendent for Kaiser Aluminum's Ravenswood (W. Va.) Works. He succeeds **Donald W. Watters,** who has accepted a position with the corporation's International div. Boyer was formerly assistant production superintendent.

Darwyn I. Brown is now president of the Seaway Steel div. of Roblin-Seaway Industries, Inc., North Tonawanda, N.Y. Previously, he was manager of product development of the Washington Steel Corp.

Edward S. Bunn has been elected vice president of Revere Copper and Brass Inc., in charge of research and development. He was formerly general manager of the company's Research and Development Dept.

Gurdon M. Butler, Jr., who directs research activities of Gladding, McBean, & Co., has been elected vice president in recognition of the greater emphasis being placed on the company's research program.

G. Robert Couch has been appointed technical advisor to the vice president, **Lars Ekholm,** who is in charge of Eastern operations for Climax Molybdenum Co. Mr. Couch was formerly in the Corporate Central Planning dept. of American Metal Climax, Inc., the parent company.

George K. Dreher is now product and market development director of Burnside Steel Foundry Co., Chicago. He was formerly with the Steel Founders' Society of America.

George R. Eusner has become executive vice president of Davis Fire Brick Co., Oak Hill, Ohio.

Charles Goodeve, president of The Iron & Steel Institute (London), has been elected a Distinguished Life Member of the American Society for Metals. A presentation was made to Sir Charles at the ASM Banquet in Detroit on October 26.

Henry H. Hausner, consulting engineer, has been appointed to the research staff of Ilikon Corp., Natick, Mass. He is adjunct professor at Polytechnic Institute of Brooklyn.

W. M. Kelly has been appointed manager, technical operations, for Union Carbide Metals Co. He has been assistant technical director, alloys operations, since 1959.

J. Howard Kittel has been promoted from associate metallurgist to senior metallurgist at Argonne National Laboratory, Argonne, Ill.

G. Letendre, director of the Mining and Metallurgical Engineering dept. at Université Laval, Quebec, Canada, has been elected to honorary membership in the Société Francaise de Metallurgie.

Edward E. McGinley has joined Koppers de Venezuela, C.A. He will be advisory plant manager at the Orinoco steel plant of Corporacion Venezolana de Guayana. Mr. McGinley was formerly assistant general superintendent of U.S. Steel Corp.'s Edgar Thomson Works.

Charles D. Michaelson has been named vice president, mining, of Kennecott Copper Corp. He has been general manager, Western mining operations, since 1955.

Ernest F. Nippes has been named acting head of the Department of Materials Engineering at Rensselaer Polytechnic Institute. He succeeds **Arthur A. Burr,** who recently became acting dean of the School of Engineering.

John C. Schottmiller is now a staff chemist with IBM Corp.'s Components div. in Poughkeepsie, N. Y. He was previously with Union Carbide Metals Co.

Curt Searight is now regional sales manager for Kaiser Refractories div., with headquarters at Mexico, Mo. He has been district manager in St. Louis since 1959.

Earl E. Swansen has been named manager of product planning and development by the conveyor and process equipment div. of Chain Belt Co., Milwaukee.

Richard W. Vollmer has been appointed assistant to the president of Strategic Materials Corp. He had previously been with Koppers Co. where he was manager of the Direct Reduction Sales dept.

Charles I. Whitman has joined the Copper Products Development Assoc. as assistant technical director. He was formerly with General Telephone & Electronics Corp.

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ANGLES BETWEEN PLANES IN CUBIC CRYSTALS

By R. J. Peavler and J. L. Lenusky

IMD Special Report Series Number Eight

This small but valuable 28-page booklet contains tables of interplanar angles in the cubic system up to {554}. Calculated on a digital computer by members of the Crystallographic Group at Westinghouse, the values were checked carefully to prevent error in transcription. Typographical errors were eliminated by reproducing the original tables. Invaluable for orientation work in many phases of physical and X-ray metallurgy. Author R. J. Peavler is a crystallographer in the Crystallographic Group of the Materials Engineering Departments, Westinghouse Electric Corp. J. N. Lenusky is a former laboratory assistant in the Crystallographic Group.

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Bureau of Mines' Research Programs

The following is a continuation of the listing of the US Bureau of Mines' research programs begun in last month's Reporter. For further information on the Bureau of Mines, the reader's attention is called to the article on p. 812.

Manganese

Although the bulk of the Bureau's program for manganese will be directed towards the economic utilization of the Nation's large low-grade and refractory resources, investigations will be made on new combinations of manganese-copper alloys and their correlation with vibration damping, magnetic properties, and effects of neutron irradiation. Other research will be concerned with the reducibility of manganese in silicate systems, bacterial leaching of manganese from low-grade ores, and a modified ammonium-carbamate procedure for recovering manganese from slimes.

Molybdenum

Molybdenum research will emphasize mining and beneficiation studies to improve molybdenum recovery and the extraction of molybdenum from its compounds by fused-salt electrolytic techniques. The Bureau's metallurgy research center at Reno, Nev., will investigate electrowinning techniques, while the Albany, Ore., center will investigate methods for preparing and reducing ultra-pure molybdenum compounds, and melting and casting of molybdenum and its alloys.

Nickel and cobalt

Recovery of nickel from lateritic ores, separation of nickel from cobalt, and recovery of nickel and cobalt from high-temperature alloy scrap are the primary points in the Bureau's program for these metals. The recovery from lateritic ores will be attempted with a process involving high-temperature sulfatization of the ore followed by water leaching to remove nickel sulfate. Recovery of nickel and cobalt from high-temperature alloy scrap will be performed at both the College Park, Md., and the Salt Lake City research centers.

Titanium

Metallurgical research on the fused-salt electrolysis of titanium compounds will be emphasized in studies on this metal. Included are studies on extractive metallurgy and mineral beneficiation and the evaluation of domestic titanium resources. Further work on titanium will be for improvement in methods for centifugal and spin casting the metal, and the development of permanent and expendable mold designs and materials. Other attempts will be made to increase the efficiency of electrostatic- and magnetic-separation processes for titanium and other selected minerals.

Vanadium

Vanadium research will be concerned with the development of vanadium-bearing alloys using high-purity vanadium. Special attention will also be given to a columbium-vanadium alloy system which has exhibited exceptional corrosion resistance in acid environments at high temperatures in preliminary tests.

Rare-earth and minor metals

Research programs are also scheduled for rare-earth and minor metals. Improved extractive, processing, and purification methods for rare-earth materials for use in the electronics and nuclear energy fields will be the primary concern of the Bureau. Research on the minor metals—rhenium, cesium, rubidium, germanium, and scandium—will be concerned with improving extraction and electrowinning processes with the aim of increasing their purity and commercial availability.

Iron and steel

The Bureau's program in ferrous metals will emphasize the development of better methods for utilizing taconite jasper-type iron formations in the Lake Superior region. Similar work, although on a somewhat smaller scale, will be conducted on deposits in several western and southeastern states. One of the more promising projects will be the partial reduction of iron oxides in pellets made from taconite concentrate. Pre-reduced taconite pellets will be charged into the Bureau's experimental blast furnace to determine their smelting characteristics. Much of this work is described in an article on the Bureau's Minneapolis Research Center on p. 812.

The steel research program is aimed at developing new steels for high-strength, low-temperature applications. Bureau metallurgists will seek more information on high-temperature reactions, the refining of molten pig iron directly into steel, and the use of uranium as an alloying agent.

* * *

GE Refractory sheet mill

The first of a series of rolling mills to produce tungsten, molybdenum, and other refractory metals is now being installed at General Electric's Euclid, Ohio plant. The $15-million installation is expected to begin operation this month with the production of tungsten and molybdenum in wide sheet form. This first hot-rolling mill is capable of producing 24-in. wide tungsten sheet and plate in thicknesses of 0.500 to 0.150 in. A second mill, to be in operation before the end of the year, will permit finishing at lesser thicknesses, and eventual production will range down to sheets 0.005 in. thick. When completed, the mills are expected to be the largest and most highly integrated production facility of its kind.

REPORTER

New Cb-base alloys

Two new columbium-base alloys for use in space-craft and missiles are now available commercially from the Du Pont Metals Center in Baltimore, Md., the company announced recently. The new alloys, known as *D-14*—a binary containing zirconium—and *D-36*—a ternary containing titanium and zirconium—are said to be readily fabricated, welded, and coated by conventional methods. They are said to retain useful strength at temperatures above 2500°F, and are specially designed to maintain high strength after heat treatment associated with the application of coatings. In addition, both alloys can be welded to form ductile weld joints.

Welding titanium plates

It may be possible to fabricate nuclear submarine hulls of titanium alloys as the result of new welding procedures developed at Battelle Memorial Institute. In a technical paper presented at the Annual Meeting of the American Welding Society, Battelle welding experts reported that they have produced crack-free welds in 120,000 psi yield, 2-in. thick titanium alloy plates. Weld joint properties equaled or exceeded the properties of the base alloy. The study is a part of a comprehensive program sponsored by the Bureau of Naval Weapons.

Welds were made in plates with a doubel-vee joint design using an automatically-controlled consumable-electrode process. To prevent contamination, all welding was done in an argon-filled chamber. The best combination of yield strength and impact properties was obtained with commercially-available Ti-6Al-4V alloy plates and an experimental 5Al-2Cb-1Ta alloy filler wire.

Hi-purity tungsten crystals

Westinghouse reports that is has developed a practical method for producing large single 99.9975-pct W crystals. Engineers of the firm have designed electron-beam zone melting equipment to produce these crystals. Starting material is special high-purity tungsten ingots. The Westinghouse tungsten crystals are ductile, even at temperatures as low as —330°F. They are made in the form of 10-in. rods, 0.2 in. in diameter, which is sufficiently large for fabrication into small parts.

First aluminum sub

An aluminum submarine designed to explore ocean depths up to 15,000 ft will be built for Reynolds International Inc. by General Dynamics Corp. Woods Hole (Mass.) Oceanographic Institution will operate the sub as part of a research program sponsored by the Office of Naval Research. Displacing 150,000 lb, the vessel will be slightly over 50 ft long and 8 ft in diameter. The sub's hull will be constructed by bolting together large, one-piece cylindrical sections of 7079-T6 aluminum forgings. The world's largest aluminum ingot already has been cast for the first section.

Largest Cb forging

At the North Grafton plant of Wyman-Gordon, the 50,000-ton, closed-die forging press has produced the largest known columbium forging. It was forged from an ingot 15 in. in diameter and 26 in. long, weighing 1300 lb. The ingot was produced by electron beam melting followed by duplex vacuum arc melting to remove impurities. Forging procedure involved ceramic spraying of the metal to prevent absorption of atmospheric gases in the 2100°-2250°F forging temperature range.

Koppers New Research Center

Koppers Co., long active in blast furnace engineering and construction and coke production, implemented a long-term commitment in research in the fields of chemicals and plastics with the dedication of its new Monroeville, Pa., research center.

The $8.5 million facility, named Somervell Park, can be expanded to house a research and support force of 1500, although present personnel total about 400. Only about one-third of the buildings planned for the 176-acre site have been completed.

A few areas of particular promise in Koppers' R&D effort include boron chemistry, plastics for use as building materials, fiber reactive dyes, and chemical intermediates. For anodized aluminum, the firm is developing a non-precipitating dye which imparts permanent coloring.

One research project that Koppers believes has great promise involves the desalinization of sea water. Known as Koppers Hydrate Process—now in bench-scale operation—it is the only known chemical approach to this problem that is under serious investigation. Koppers believes that, because its process calls for a lower energy input, it gives promise of substantially lower original investment and operating cost. It is expected that this project which is being carried forward in cooperation with the US Dept. of the Interior, will move into pilot plant production in the near future.

The UNITED ENGINEERING CENTER

AIME's New Home

Do you remember . . . when . . . ?

May 6, 1906—Cornerstone laying for the Engineering Societies Building. In the picture can be seen, Miss Margaret Carnegie, now Mrs. Carnegie Miller (with the bouquet); Andrew Carnegie; and Rossiter W. Raymond, a founder of AIME (to the right of Miss Carnegie).

After more than a half-century in the Engineering Societies Building on Manhattan's 39th Street, the AIME—together with the other Founder Societies—has moved its headquarters to the new United Engineering Center on the United Nations' Plaza. Such a move has been made possible by financial contributions from industry and from members of the various societies.

The old headquarters was, on the other hand, financed largely by the generosity of one individual, Andrew Carnegie. In March 1904, he acquiesced to a proposal of major national engineering organizations that he support their hope for a common headquarters and a unified engineering library. At that time he wrote, "It will give me great pleasure to devote, say, one and a half million dollars to the erection of a suitable home for you all in New York." Later, Mr. Carnegie's agent assembled several properties occupied by residences on 39th Street, and construction began.

For two days, April 16 and 17, 1907, the engineering profession, with dignity and pride, officially realized its dream of many years. The dedication was so inspiring a symbol of achievement and purpose as to attract messages from President Theodore Roosevelt, the President of Mexico, and the Governor General of Canada. Participants in the two-day dedication program included, besides Mr. Carnegie, the following distinguished persons: Alexander Graham Bell, Nicholas F. Brady, C. F. Brush, Cleveland H. Dodge, James Douglas, Alexander Dow, Thomas A. Edison, John Hays Hammond, Peter Cooper Hewitt, Samuel Insull, Clarence H. Mackay, James H. McGraw, Michael I. Pupin, Sir David Salomons, Ambrose Swasey, George Westinghouse, and C. C. Worthington.

John Hays Hammond, President of the American Institute of Mining Engineers, was one of the speakers. E. E. Olcott, President of the United Engineering Society (predecessor of the United Engineering Trustees Inc.) received the gold key to the building. Tiffany's has incorporated in it a few particles of John Marshall's original 1848 gold find at his California saw mill.

The dedication was a particularly happy event for Mr. Carnegie. "Much of my youth has passed away", he said in his talk. "But here is a rock upon which I can rest . . . I look forward to the future of this building, and I know that the organizations to whom it is devoted will advance and continue to meet the developing needs of our age."

Left, Members' Writing Room, AIME, about 1925.

Right, Engineering Societies Building, 29 West 39th Street, New York.

They have done just that, and in the process their memberships have grown increasingly large. AIME, for example, had some 4200 members in 1907, but by 1960 there were 36,700. The original 13-story building was extended by three floors, but the growth of the engineering societies finally surpassed the ability of the 39th-Street structure to house their headquarters.

The site

Serious thought about a new home for the national engineering societies began to take shape about 1950. In 1953 a gift of land was offered in Washington, D.C., and later individuals and groups in Detroit, Baltimore, Philadelphia, Hoboken, St. Louis, Chicago, and Pittsburgh made offers. At first the AIME Board voted to restrict the site to a New York location, but offers from other cities, particularly Pittsburgh and Chicago, were quite attractive, and delegations visited each of these cities to survey the possibilities.

Early in 1954, a committee composed of the presidents of five societies (ASCE, AIME, ASME, AIEE, and AIChE) was appointed to decide on where the building should be. The United Engineering Trustees (UET) voted unanimously to keep the building in New York. But the Committee of Five Presidents was not so convinced, and they recommended that Pittsburgh be selected on the basis of lowest capital cost and annual expenditure.

The AIME Board decided to postpone its decision, as AIEE and ASCE had done. On June 8 a letter from Mervin J. Kelly, signed by eight presidents of educational institutions and thirteen heads of large industrial enterprises was received; it recommended that a large, independent, management or engineering firm be engaged to survey the matter—its decision to be based on the long range interest of the profession. The signers agreed to make a well-organized effort on a national basis to raise additional outside funds to construct the new building. The Board voted to take advantage of the Kelly offer and to hold the Pittsburgh offer in abeyance.

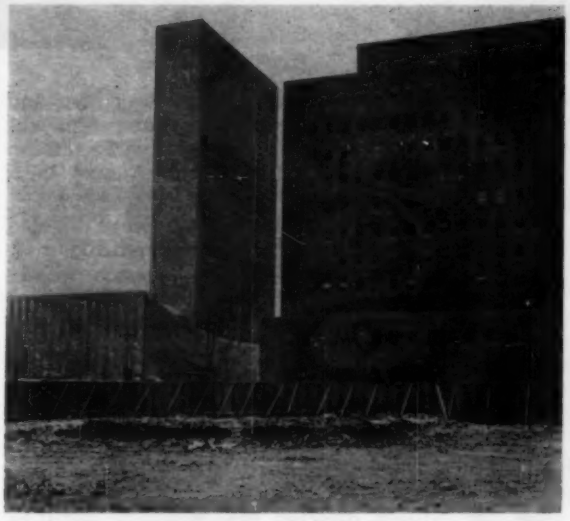
Late in 1955, the firm of McKinsey & Co. was selected to make the survey. And some six months later McKinsey's task force reported their decision that the engineeering building should remain in New York, utilizing the present site, if possible, otherwise some other midtown location. This was put to a mail vote of the AIME Directors who voted, in mid-summer 1956, 33 to 2 to stay in New York.

In February 1957 it was reported that, because of the exorbitant cost, rehabilitation of the old building was not feasible. In a few months, a site on First Avenue between 47th and 48th streets, comprising 37,500 sq ft was purchased, and a 20-story building, with 200,000 sq ft of floor space and expansion to 350,000 sq ft was decided on.

Financing

Financing then became the immediate problem. In April 1957, AIME President Grover J. Holt appointed a committee to assist the UET in making plans for raising money from members of the societies concerned. Of the total of $10 million that the building was planned to cost, $5 million was to be raised from industrial companies employing engineers, $3 million from members of the societies that would occupy space in the new building, and $2 million from the sale of the old building and from cash that UET had in a sinking fund.

Demolition



Cleared Site

Construction

Then the Big Day Friday September 1, 1961

The industrial campaign got under way first, and by May 1958, when the member campaign was getting started, $3 million of the allotted $5 million from industry, had been pledged. By August 1961, the total had reached $4,982,936.

The late winter and spring of 1958 were devoted by all of the Founder Societies to organizing their member gifts campaigns. Quotas for each society had been set in November 1957, approximately depending upon their memberships. Other engineering societies that planned to take space in the new building later also accepted quotas, bringing the total of the quotas assigned to all societies to $3,740,000.

With Joseph L. Gillson as the directing head of the AIME Member Gifts Committee, Edward H. Robie was selected as secretary and took over in April 1958. Dr. Gillson directed the campaign until he became Institute President in February 1960, when Lloyd Elkins assumed the job. Since early 1959, Mrs. Winifred D. Gifford served as assistant to Mr. Robie. Under this able direction, the campaign was considered terminated on Sept. 1, 1961 with a total of $511,004 pledged, or 102.2 pct of the AIME quota!

Construction

The first physical step toward the realization of the new United Engineering Center was the demolition of existing buildings on the site. Ground breaking ceremonies for the center were witnessed by a crowd of some 500 society members, foreign visitors, and guests on October 1, 1959. Amid blustery winds and intermittent downpours, the Hon. Herbert Hoover turned the first shovelful of dirt, signaling the beginning of construction. Work progressed rapidly, and the last beam of the steel structure was lowered into place on July 26, 1960. Completion of the exterior and the interior required more than one year.

The move

After months of planning, the big move finally took place on the Labor Day week-end of 1961. Vans began moving into place about 5 p.m. on Friday, and Tuesday found the AIME headquarters occupying 9600 sq ft of space on the 13th and 14th floors of 345 East 47th Street.

The move of the 13 engineering societies, the Library, and the Engineering Index involved office equipment for a staff of some 600 persons who comprise the headquarters staffs. It was handled with astounding smoothness and almost without a hitch.

The building

The United Engineering Center is an imposing structure of glass and limestone rising from a granite base. Stainless-steel mullions, column covers, and window frames accentuate the gray-blue color motif used in the glass spandrels for the full height of the building. The same gray blue is carried into the structure in the lower lobbies and in the public rooms throughout the structure. Most of the facilities serving all tenants of the building and the public are contained in the low block, which covers almost the entire property of 37,000 sq ft.

The main entrance to the structure is from the 47th Street terrace into a lobby walled in Georgia Cherokee marble, with floors of bluish gray terrazzo. On the United Nations' side of the lobby is an Exhibition Hall. Here it is planned to have changing displays, illustrating the many contributions made by all branches of the engineering profession to world progress. Glass from floor to ceiling, the full length of the Plaza side provides a show window for the passer-by. Provision has been made for flexibility in the lighting of displays.

On this floor there is a meeting room for 430 persons which can be subdivided into three rooms of equal size. Special provision is made for the presentation of illustrations from a projection booth.

From the lobby, four automatic elevators serve the needs of the building. Space is provided for two more elevators, which will be required when additions are made to the structure. Corridors lead to private dining and conference rooms with capacities varying from 20 to 100 persons.

Below the main floor, is an employees' lounge and dining room, seating 250. It is situated around a landscaped sunken court. Also on this level are the switchboard, building maintenance shops, and the like.

The individual societies have their offices in the 69x139-ft, 20-story tower section which reaches a

Moving to United Nations Plaza

height of 283 ft. from the curb. The 15th and 16th floors are not finished and are available for expansion. Another provision for expansion is in a planned connecting structure on the northwest side of the building over the library and book stacks, where as much as 8500 sq ft can be added per floor from the third through the eighth floors, and 6000 sq ft per floor from the ninth through the twelfth.

Simple, but heavy all-welded framing, with a cantilever to avoid columns on the United Nations side of the building in executive suites, is the basic structural feature of the building. Air ducts are framed through webs of the beams to permit a 9-ft floor-to-ceiling height and a story height of 12.5 ft. Unusual trusses are provided to carry a future 12-story addition over the main meeting room.

A most interesting feature of the United Engineering Center is the exterior sheath of the building. Vertically, a 6-ft height of plate glass, ¼ in. thick, alternates with a 6-ft height of light blue Spandrelite (a ceramic structural glass about ⅜ in. thick). Four windows, 5 ft wide, fill the space between columns at a spacing of 22 ft on centers. Stainless steel is used for window frames, between the glass and Spandrelite, and for the column covers. None of windows in the building may be opened.

A striking feature of the building's mechanical system is its integrated ventilation control system. The maintenance man can sit at a data center in the basement, and graphically view the operation of the heating and air conditioning systems, and control them in any part of the building.

Steam from the Consolidated Edison system is used to heat the building and to furnish energy for the operation of water chilling machines.

The occupants

Fourteen societies which moved from the old Engineering Societies Building have been joined by five other professional groups to make what is believed to be the largest concentration of professional engineering societies in the world. Together they represent a world-wide membership of some 300,000 engineers.

The owner and operator of the United Engineering Center is United Engineering Trustees Inc., which is an agency of the five Founder Societies—American Society of Civil Engineers; American Institute of Mining, Metallurgical, and Petroleum Engineers; American Society of Mechanical Engineers; American Institute of Electrical Engineers; and American Institute of Chemical Engineers.

Other occupants are: American Institute of Consulting Engineers; American Institute of Industrial Engineers; American Society of Heating, Refrigerating, and Air-Conditioning Engineers; American Welding Society; Engineering Foundation; Engineering Index; Engineering Societies Library; Engineers' Council for Professional Development; Engineers Joint Council; Illuminating Engineering Society; Society of Women Engineers; The Municipal Engineers of the City of New York; United Engineering Trustees Inc.; and Welding Research Council.

Library and index

Two facilities of the United Engineering Center which are of particular interest to engineers, scholars, and research workers alike are the Engineering Societies Library (ESL), and the Engineering Index.

Begun more than a half century ago by contributions of the libraries of the engineering societies

(Continued on page 792)

Reading Room of the Engineering Societies Library

And Here We Are . . . .

Receptionist, Mrs. Irene Sharp

On the 14th Floor

AIME

General Secretary, Dr. Ernest Kirkendall

On the 13th Floor

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345 East 47th Street, New York

On the 13th Floor
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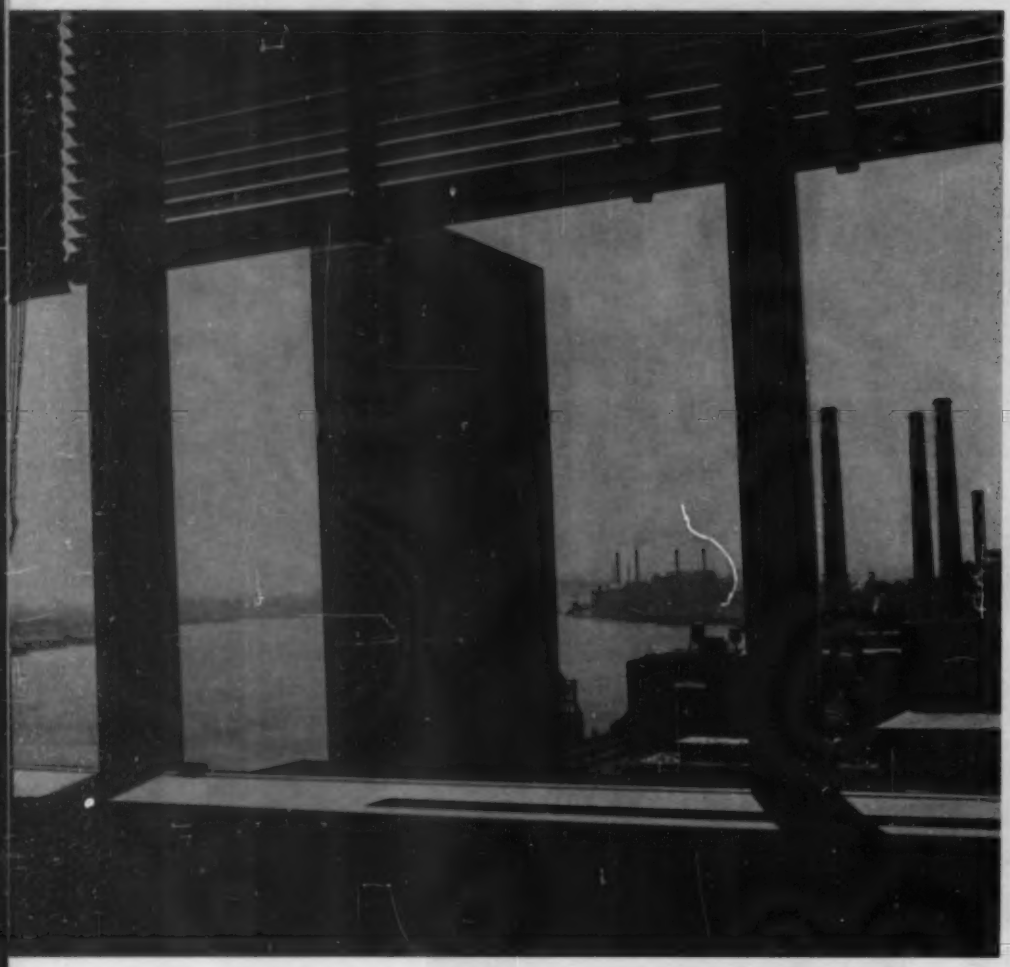
Secretary, Robert W. Shearman

Mrs. Adeline Stevens

Miss Joyce A. Lovell

IMD Secretary, Douglas C. Johnston dictating to Miss Normajean Rockett.

Miss Irene Carey



Photos by David Cain, Molly Cook, and others.

that maintain it, the Engineering Societies Library has grown to a size and degree of service in its field that probably has no match in the world. The Library has a reservoir of 180,000 volumes, 27,000 maps, and 10,000 indexed bibliographies. In addition, it files many thousands of technical papers and receives 3400 periodicals and other serial publications from 45 countries. In its new home in the United Engineering Center, ESL has a potential capacity of 255,000 volumes; it has an 81-seat reading room, five-tier book stack area, and an air conditioning system designed to preserve books under ideal humidity and temperature conditions.

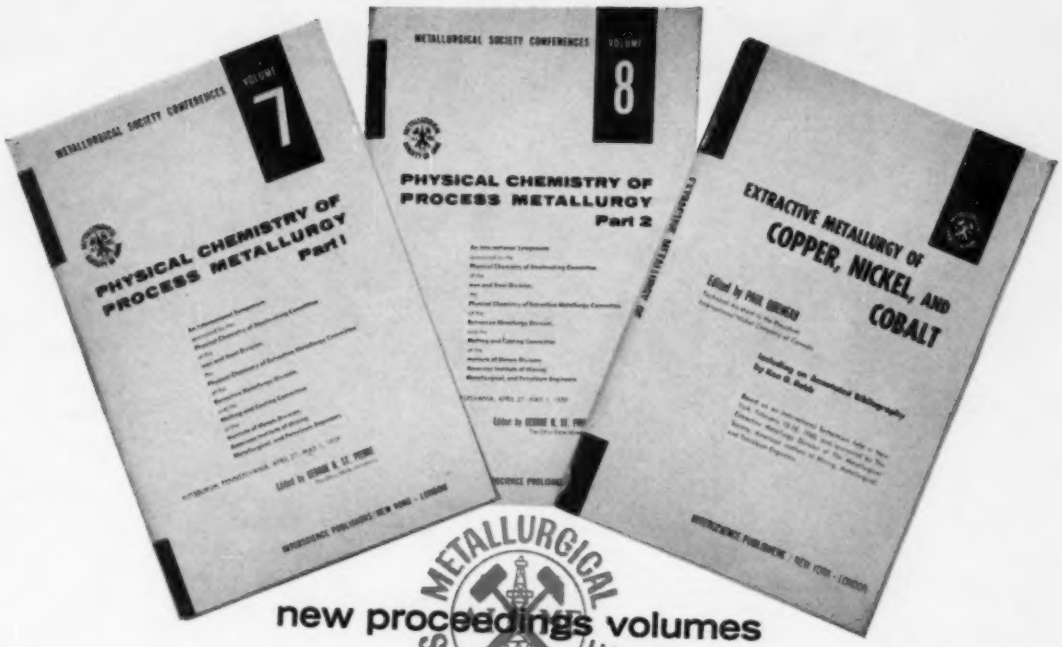
Closely allied to ESL, is the Engineering Index Inc., another non-profit organization and a distinct entity. It is a reviewing service, annotating and indexing on the basis of engineering significance, the current technical periodicals received by and housed in the Library. Index cards are mailed weekly to subscribers in each of 249 fields of interest. And at the end of the year a bound volume is published which contains all of the information distributed for a full calendar year.

Dedication

Now fully occupied, dedication of the 20-story, $12-million United Engineering Center is being held on November 9. Herbert Hoover, Senior Past President of AIME, as well as former President of the United States, is Honorary Chairman of the dedication committees. Dr. Eric A. Walker, President of the Pennsylvania State University is the principal speaker.

The United Engineering Center has already become a monument among the buildings surrounding the United Nations Plaza. Significantly so, since as a close neighbor of the United Nations, world delegates to the UN will become increasingly aware of the resources of skill and achievement of American engineers, symbolized by the new Center. Its congregation of societies and organizations can represent vital contributions to the advance of civilization.

Across the street to the south is the Carnegie Foundation for International Peace, a symbol, with the United Nations, of the world the engineers are trying to relieve of drudgery by adapting the forces of nature to the needs of man.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edited by **GEORGE R. ST. PIERRE**

CONTENTS *(Showing Section titles only)*

Part I

(35 papers)

Physical Chemistry of Metallurgical Phases — Physical Chemistry of Oxide Phases — Thermodynamics of Metals — The Nature and Structure of Liquid Metals — Transport and Mixing — Solubility and Phase Equilibria in Metals Systems

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Extractive Metallurgy of Copper, Nickel, and Cobalt

Based on an International Symposium sponsored by the Extractive Metallurgy Division of The Metallurgy Society of AIME; New York, February 15-18, 1960

edited by **PAUL QUENEAU** including an Annotated Bibliography by **Ken G. Robb**

CONTENTS ***(Showing only Session titles: A total of 24 papers were given, each followed by discussion.)***

General — Fuel-Fired Smelting and Converting — Electric Furnace Smelting — Atmospheric and Elevated Pressure Leaching — Refining — Bibliography

May, approx. 650 pages **Members: $18.00, Nonmembers: $22.50**

Response of Metals to High Velocity Deformation

Volume 9 of Metallurgical Society Conferences

Sponsored by the Physical Metallurgy Committee, Institute of Metals Division, The Metallurgical Society of AIME, Estes Park, Colorado, July 11-12, 1960

edited by P. G. SHEWMON and V. F. ZACKAY

CONTENTS

High Velocity Deformation (6 papers)—Shock Phenomena in Metals (10 papers)

May, 492 pages **Members: $14.40, Nonmembers: $18.00**

A complete listing of forthcoming and previously published volumes is available from The Metallurgical Society or Interscience Publishers upon request.

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Steel costs lowered by modern technology

New OXWELD C-66 cutting torch—cuts up to 30 in. with natural gas as fuel. Field operations have shown savings up to 15% in operating costs.

UNIONMELT Submerged Arc welding "double-joints" 24-in. diameter steel pipe into 60-ft. lengths at the pipe mill, speeds major pipeline construction.

FORWARD

LINDE COMPANY

UNION CARBIDE

Republic Unveils Warren Hot Strip Mill

Republic Steel Corp. has placed in operation at Warren, Ohio, a new 56-in. continuous hot strip mill incorporating many automatic controls. This mill, costing $55 million, completes a major phase of Republic Steel's $375 million modernization and improvement program started two years ago.

Initial capacity of the new mill is 140,000 tons per month. Provisions have been made for the installation of a third slab-heating furnace which will increase capacity to 210,000 tons per month. The new mill replaces an obsolete 42-in. strip mill with a capacity of some 70,000 tons per month.

Slabs fed to the mill can vary in width from a minimum of 14 in. to a maximum of 52 in., in thickness from 5.5 to 10 in., and in length from 23 to 28 ft. Maximum slab weight is 50,000 lb.

The new mill is designed to meet present customer needs and anticipated future requirements. Power is particularly important in order to enable the mill to handle tough alloy and stainless steels as well as the more conventional carbon steel. The roughing end of the new mill incorporates motor drives with a total of 15,500 hp and the finishing end 34,000 hp. Main motor drives range up to 6000 hp.

The mill incorporates numerous examples of automatic and semi-automatic controls. At the slab heating furnaces, closed-circuit television enables furnace operators to watch the movement of slabs out of the furnace. The various functions of the reversing roughing mill and its related facilities can be controlled automatically through the use of an efficient punch card system. In the finishing stands, strip gauge is controlled automatically by load cells which produce a signal if strip thickness varies from prescribed tolerances. This signal, amplified through a series of electronic units, actuates a unique hydraulic control known as a Wheeler Automatic Screw-Down Control which makes immediate adjustments of the mill roll openings to correct rolling pressures. Finally, a series of radiation gauges—X-ray and infra-red—continuously record strip thickness and width, even though the strip is speeding by at some 2400 ft per min.

Large coil size is another special feature of the new mill, which is designed to roll 50,000-lb coils up to a maximum width of 52 in. and a diameter of 73 in. These large coils minimize the need for welding ends together, thereby permitting greater efficiency in fabricating operations.

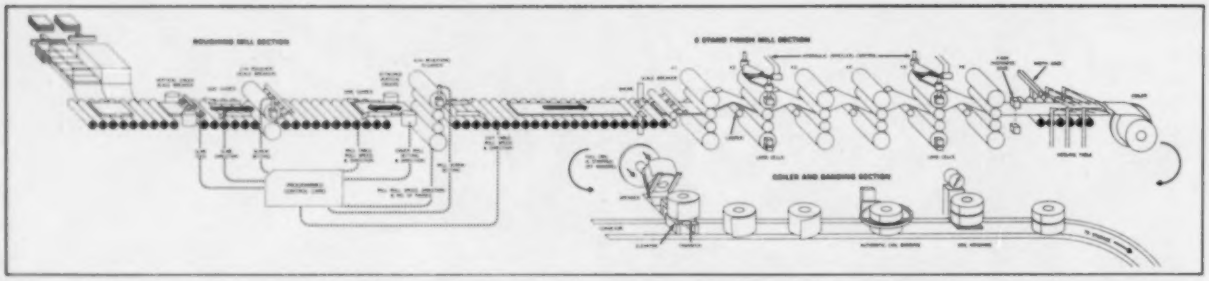
Other facilities being constructed at Warren include a pickling line, continuous galvanizing line, cold mill, annealing line, and cold temper mill.

In describing the new mill, Thomas F. Patton, president of Republic Steel stated:

"The $55 million we put into the mill is about 10 times the investment in the facility it replaces. Even taking into account the difference in the capabilities of the two mills, this is a tremendous disparity.

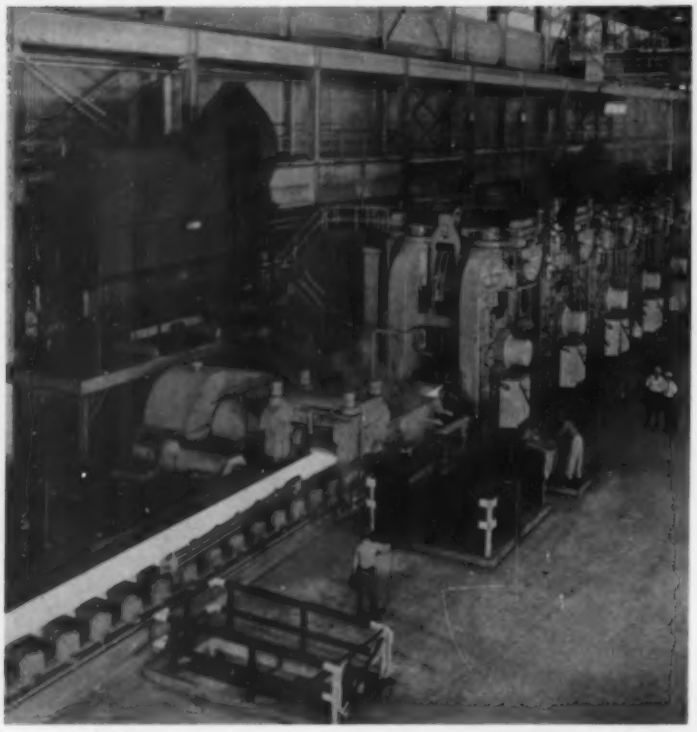
"Yet, this investment had to be made . . . if we are to remain competitive and if we are to help a growing population realize a continuing rise in our standard of living."

(Illustrations on following page)



Republic's New Warren Hot Strip Mill

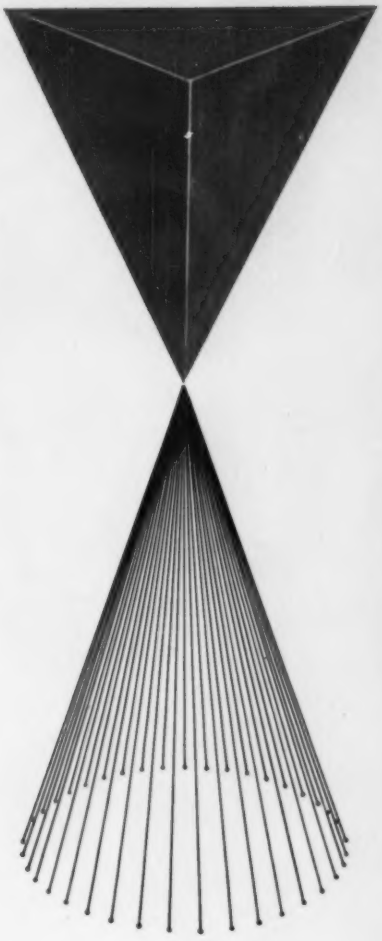
(Continued from page 793)



Sheet steel, is shown entering a series of six finishing mill stands. In these stands, the steel is automatically rolled to the customer's specified thickness and then run out on a 393-ft long cooling table prior to being coiled.

While slabs are starting their reduction into strip on the reversing roughing mill, an operator checks a control panel in one of the pulpits at the new strip mill. Slab feed and direction, roll openings, mill table roll speed, and the number of passes can be controlled automatically by the punched card system partially shown in the right foreground.

Coils prior to weighing and banding. The coils from the new mill weigh up to 50,000 lb each and vary in width from 14 to 52 in. wide.



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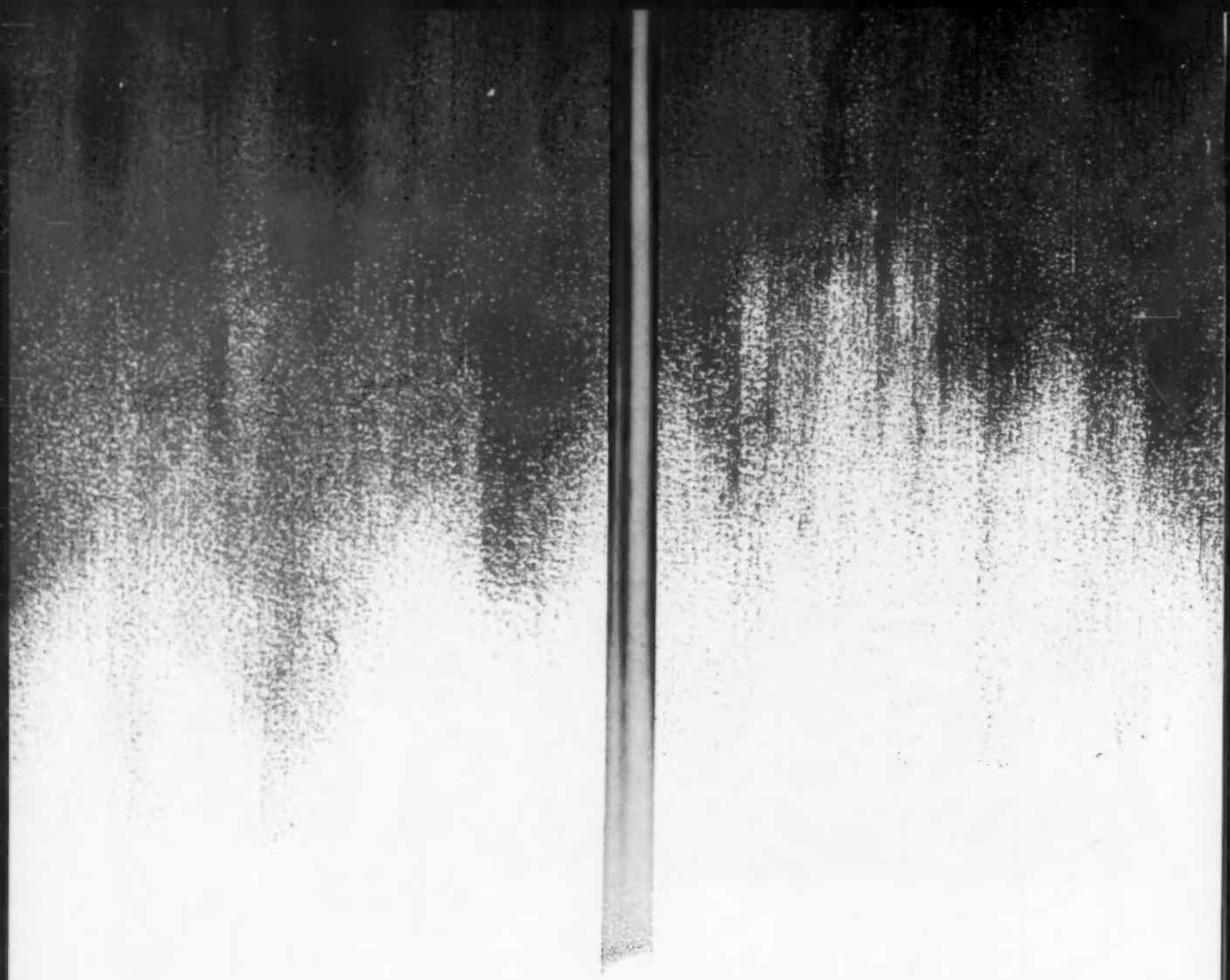

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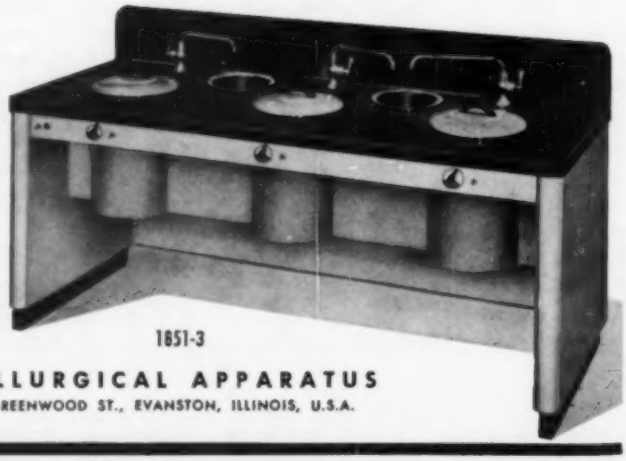

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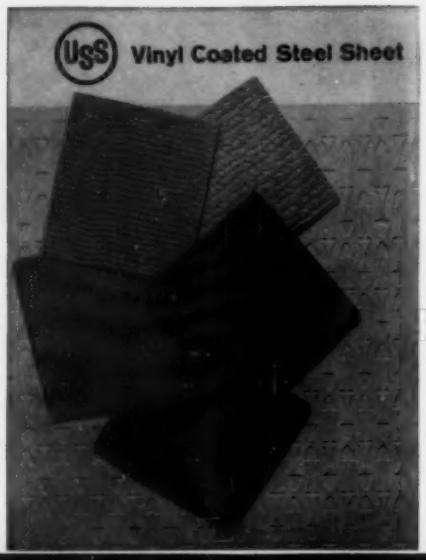

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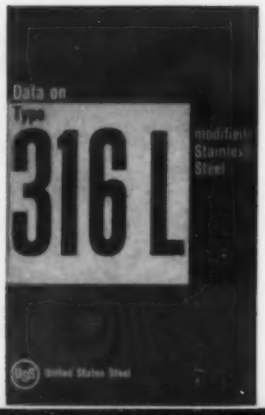

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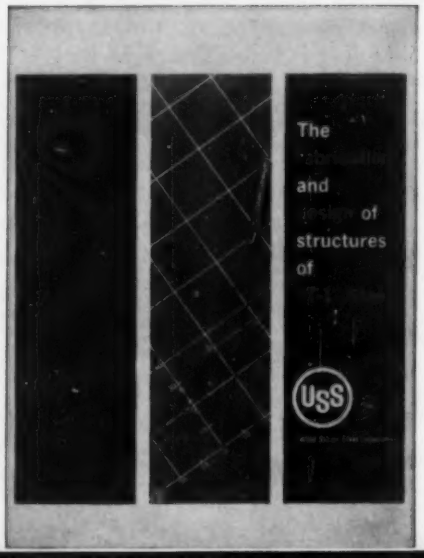

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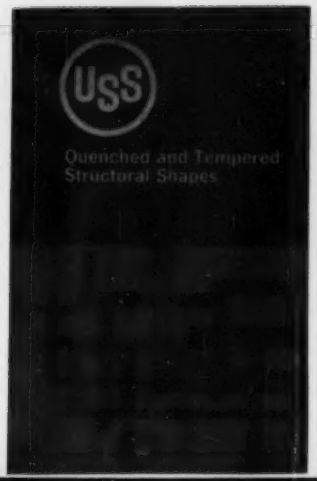

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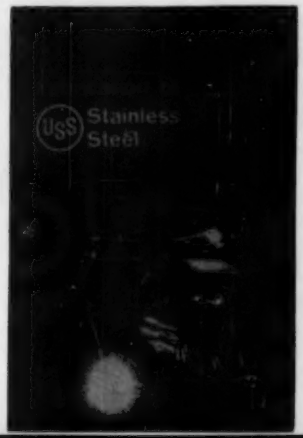

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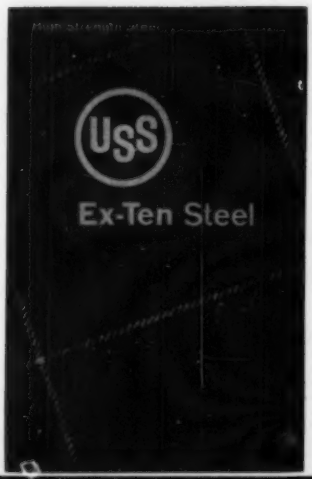

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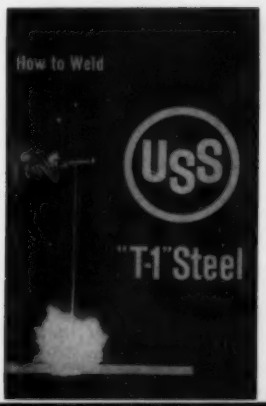

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SMALL ALLOY ADDITIONS

This paper presents the effects of various small alloy additions on the mechanical properties and microstructure of hot-worked, silicon-killed SAE 1020 steel.

by R. A. Leeper, T. W. Merrill, and A. F. Sprankle

High-strength low-alloy steels that are fabricated and used in the hot-rolled condition have constituted an increasingly important segment of steel production over the past 20 years. Most of these steels go into flat-rolled products which can be readily formed and welded. In some types, superior corrosion resistance is also included. Recently, there has been considerable emphasis placed on the development of low-alloy steels where very small amounts of a single alloying element are added.[1-10] In view of this current specialized interest, it was decided to compare a variety of small alloy additions of both single alloying elements and alloys containing combinations of elements in an effort to determine the most suitable alloys from both a technical and practical viewpoint.

A total of 39 ingots were produced from induction furnace melts of AISI 1020 steel, to which base composition various small alloy additions were made. The alloys added contained the elements, columbium, vanadium, boron, and titanium, either singly or in combination

A tabulation showing the chemical composition of the various alloying agents is given in Table I. The chemical composition of the heats and the ingots produced, together with the weight of ferroalloy added is shown in Table II. Recoveries of columbium and vanadium, added as single alloy additions were calculated; the average recoveries were 82.5 and 91.9 pct for columbium and vanadium, respectively.

Melting and casting procedure

Silicon-killed AISI 1020 steel heats were produced in an induction furnace under argon atmosphere protection in order to hold nitrogen content close to that of open-hearth steels, and nitrogen checks indicated that this had been accomplished. High-purity ingot iron was used for melting stock. Following meltdown, the bath was killed with an addition of 22 pct ferrosilicon. After slag-off, pig iron and electrolytic manganese were added. When these alloys were in solution, the bath was again slagged-off, blocked with an addition of 50 pct ferrosilicon and the temperature adjusted to 2900°F.

For the first series—No. 3 through 13—300-lb heats were melted, and each heat was split into three, 100-lb taps. Alloys were added in the ladle during the first 2 taps. No addition was made to the last tap from each heat, which was used for comparison with the steels to which the various alloys were added. All alloys were added as −8 mesh, except for the ferrocolumbium, Alloy No. 1, which was −20 mesh. Time between taps was held to approx 3 minutes, and a sample for analysis was poured from the ladle at the start of the ingot teem.

Ingots in the first series were cast in 4-in. diam, sand-backed, sheet steel round molds approx 22½-in. long, excluding the hot top. After cooling and stripping, the hot tops were removed and 5-in. lengths were sawed from the ingots for forging.

Heats 15 through 19 were 100-lb induction furnace melts; therefore, splitting was unnecessary. The melting and casting procedure was the same as for heats 3 through 13, except that 4-in. square cast iron molds were used instead of the round molds.

Ingot to bar conversion

A technique was developed (heats 3 through 13) for direct forging of the ingots to ½-in. thick plate that required no reheating during reduction. Starting temperature was 2200° ± 25°F and finishing temperature was held to approx 1550°F. The plates were cooled in still air. This practice was aimed at duplicating, as closely as possible, the reported commercial hot-rolling practice for this type of product. Round bars of 1¼-in. diam were also forged for the purpose of determining the hardenability of these steels.

A combination forging and rolling mill practice was used on heats 15 through 19. The 4-in. square ingots were soaked at 2200°F for 1 hr and 50 min, followed by hammer forging to 2½ x 4-in. flat bars using an 8000 lb hammer. Without reheating, the bars were rolled to a final size of ½-in. thickness x 3¾-in. width. This reduction required 6 passes on a 10-in. three-high hand mill. Starting temperatures averaged 1800° ± 50°F, and finishing temperatures were approx 1625°F for the rolling operation.

Evaluation of properties

Standard ASTM rectangular tensile specimens with 2-in. gauge length were used to determine tensile properties. For the first series (3 through 13), the specimens were machined to ⅛-in. thickness, and for the second series (15 through 19) the specimens were taken to approx ⅜-in. thickness. Standard keyhole Charpy specimens were used to determine the impact strengths from room temperature to −40°F for all steels that had shown any worthwhile increase in yield strength in comparison with the base steel. Both tensile and impact strengths were run in triplicate; hardenability data were obtained from standard Jominy specimens which were

R. A. LEEPER, T. W. MERRILL, and A. F. SPRANKLE are with Vanadium Corp. of America.

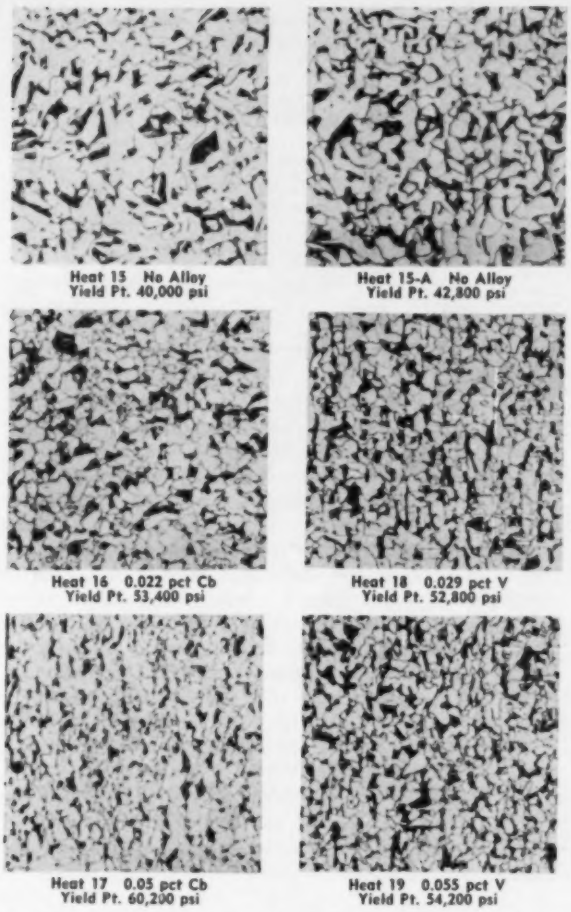
Heat 15 No Alloy
Yield Pt. 40,000 psi
Heat 15-A No Alloy
Yield Pt. 42,800 psi
Heat 16 0.022 pct Cb
Yield Pt. 53,400 psi
Heat 18 0.029 pct V
Yield Pt. 52,800 psi
Heat 17 0.05 pct Cb
Yield Pt. 60,200 psi
Heat 19 0.055 pct V
Yield Pt. 54,200 psi

Fig. 1—Microstructure and yield points of as-rolled steels, 2 pct Nital etch for 40 sec, 100X.

end quenched from 1700°F. The results of these tests are presented at a later point in this article.

Microexamination of structure and as-rolled grain size determinations were made of each steel. In general, the microstructures of all steels were similar except that the special additives produced a slightly finer grain size. There was, however, a definite difference in the carbide formation of the columbium vs vanadium treated heats, with the columbium treated heats showing a tendency to form wide carbide grain boundaries which partially encircled some of the ferrite grains. This condition is depicted in the photomicrographs in Fig. 1, and more clearly at higher magnification in Fig. 2.

Results

A review of the tensile strength determinations shows that of all the various ferroalloy combinations tried, only ferrocolumbium and ferrovanadium (or combinations of these) gave consistent improvement in hot-worked mechanical properties. The improvement in tensile properties included a higher yield to tensile strength ratio. An addition of 0.02 pct Cb or V increased yield points approximately 4000 to 6000 psi. The 0.06 pct additions gave increases of about 6000 to 10,000 psi. Vanadium Grainal #1 increased the yield point over 5000 psi for a 1.43 lb per ton addition, but the 4.3 lb per ton addition only increased the yield point 500 psi over the smaller addition.

Tensile strengths of the forged heats, 3-1 through 10-3, failed to show any worthwhile increase in the alloyed over the unalloyed steels. However, forged heats 11-1 through 13-1 (Cb-V and Cb-V-B) did show noticeable increases in tensile strengths over the untreated steels. Hot-rolled heats, 15 through 19, all showed consistently higher tensile values than their untreated counterparts.

The columbium-vanadium and columbium-vanadium-boron additions showed appreciable increases in yield point. The Cb-V-B alloy, containing 6.24 pct B, increased the yield point over 5000 psi for the 0.88 lb per ton addition, but the 2.64 lb per ton addition decreased the strength below that obtained for the smaller addition. This is the only occurrence of such behavior and may be due to testing variables since the tensile values are in proper order.

The forged steels, 3-1 through 13-3, that showed appreciable increases in yield strengths did not increase in tensile strength correspondingly. The rolled heats, 15 through 19, did show consistent tensile strength increases, together with increased yield-to-ultimate strength ratios. Usually, the increase in yield-to-tensile strength ratios was about 10 pct. Elongation values ranged from 22.3 pct to

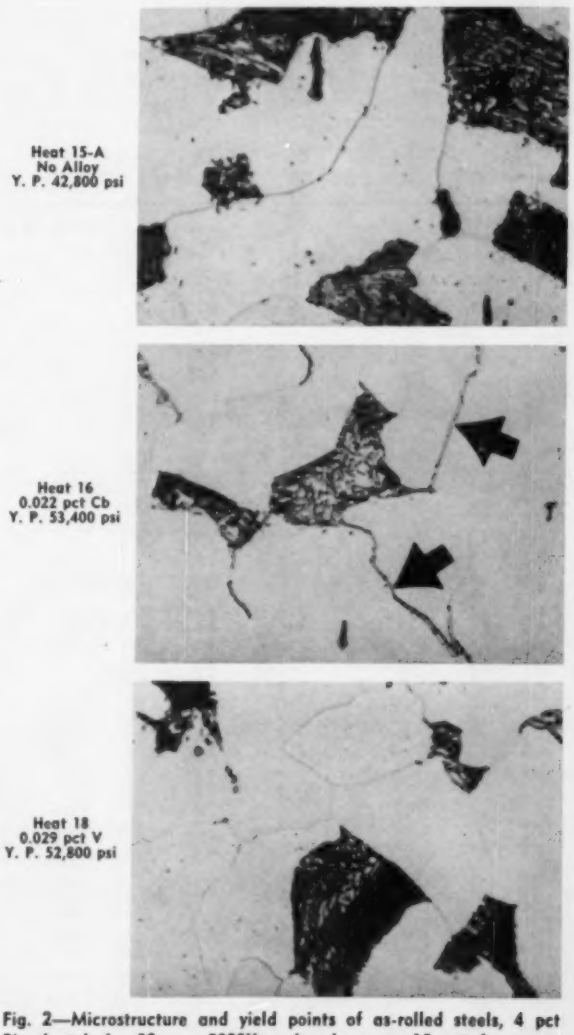

Fig. 2—Microstructure and yield points of as-rolled steels, 4 pct Picral etch for 30 sec. 2000X, reduced approx 15 pct for reproduction.

Table I. Chemical Composition of Ferroalloys, Pct

Alloy No.	Designation	Cb	V	Ti	B	C	Si	Al	Zr	Ta	W	Mn
1	Ferrocolumbium	46.00	—	0.07	—	0.67	6.72	0.07	0.18	2.46	2.08	0.82
2	Ferrocolumbium	65.40	—	0.24	—	0.10	0.98	0.29	<0.01	4.95	0.05	2.18
3	Ferrovanadium	0.025	51.70	0.10	0.006	0.86	6.89	0.35	0.001	—	0.0007	0.22
4	Vanadium Grainal No. 1	0.034	24.71	14.59	0.20	0.13	0.14	9.94	0.024	—	—	1.21
5	Grainal No. 79	—	0.32	20.96	0.54	0.16	2.90	13.25	2.46	—	—	7.60
6	Med C FeTi	0.004	0.81	20.44	0.002	3.53	2.24	1.27	0.02	—	—	0.03
7	V-B Alloy	—	40.00	0.09	6.09	0.085	1.03	2.07	—	—	—	—
8	V-B-Ti Alloy	—	40.02	4.96	7.52	0.072	1.14	3.16	—	—	—	—
9	Cb-V Alloy	29.10	34.55	0.11	0.020	0.04	0.41	0.12	<0.01	2.13	0.02	0.84
10	Cb-V-B Alloy	28.30	35.50	0.13	1.52	0.05	0.46	0.16	<0.01	2.06	0.02	0.92
11	Cb-V-B Alloy	28.07	20.75	0.11	6.24	0.052	1.32	0.23	0.06	2.04	0.01	—

33 pct on the forged alloy treated product and from 28.7 to 37.8 pct on the hot rolled.

Impact values obtained from the keyhole Charpy specimens for the forged and rolled heats are presented in Figs. 3 and 4.

Columbium was the only addition that decreased hardenability. This has been reported by other investigators[6,7] and is apparently due to the strong carbide-forming characteristic of columbium. Carbon impoverishment is caused by the formation of columbium and columbium-iron carbides and their segregation to the grain boundaries of the ferrite matrix. Additionally, the grain size of the columbium-treated end-quenched hardenability specimens was two ASTM standard grain size numbers smaller than the base heat. Smaller grain sizes are known to give lower hardenability.

Medium carbon ferrotitanium and columbium-vanadium had practically no effect on hardenability. Vanadium and Grainal #1 increased hardenability only slightly above that obtained for the base steels. Grainal #79, vanadium-boron-titanium, vanadium-boron, and columbium-vanadium-boron, all increased hardenability, the heavier additions showing the most pronounced increases. It should be noted that boron contents were greater than 0.002 pct in all steels that showed an appreciable increase in hardenability, and also that no correlation appeared to exist between end-quench hardenability results and hot forged or rolled physical properties.

A comparison of the hot-worked ferrite grain size of heats 3 through 19 showed about an average of one ASTM grain size number coarser for the base heats as compared to those alloy treated. Metallo-

Table II. Chemical Composition of Melts

Heat & Ingot No.	Alloy Added		Lb/ton Added	Steel Analyses, pct									
	No.	Type		C	Mn	Si	Cb	V	B	Ti	Al	Zr	N
3-1	2	FeCb	0.68	0.23	0.44	0.18	0.018						
3-2	1	FeCb	0.97	0.22	0.42	0.19	0.019						
3-3		None	—	0.20	0.37	0.18	Nil						
4-1	2	FeCb	2.03	0.24	0.39	0.23	0.051						0.0048
4-2	1	FeCb	2.91	0.22	0.40	0.25	0.063						0.0052
4-3		None	—	0.23	0.39	0.26	Nil						0.0048
5-1	3	FeV	0.86	0.22	0.48	0.24		0.018					
5-2	3	FeV	2.58	0.23	0.45	0.28		0.062					
5-3		None	—	0.26	0.46	0.28		0.003					
6-1	4	Grainal No. 1	1.43	0.22	0.42	0.20		0.015	0.00038	0.009	0.010		
6-2	4	Grainal No. 1	4.30	0.21	0.42	0.23		0.047	0.00068	0.018	0.008		
6-3		None	—	0.20	0.37	0.23		0.002	0.00036	0.003	0.006		
7-1	5	Grainal No. 79	3.00	0.21	0.46	0.22			0.00063	0.016	0.007	<0.009	
7-2	5	Grainal No. 79	9.00	0.22	0.42	0.23			0.0022	0.061	0.023	0.009	
7-3		None	—	0.23	0.40	0.24			0.00036	0.003	0.017	<0.009	
8-1	6	Med C FeTi	6.00	0.21	0.41	0.23				0.0045			
8-2	6	Med C FeTi	10.00	0.21	0.39	0.25				0.018			
8-3		None	—	0.22	0.35	0.23				0.0016			
9-1	7	V-B Alloy	0.62	0.21	0.47	0.18		0.011	0.0013				
9-2	7	V-B Alloy	1.85	0.21	0.47	0.22		0.036	0.0032				
9-3		None	—	0.21	0.45	0.30		0.001	0.00036				
10-1	8	V-B-Ti Alloy	0.62	0.23	0.41	0.21		0.011	0.0015	0.0023			
10-2	8	V-B-Ti Alloy	1.85	0.21	0.40	0.23		0.032	0.0038	0.0028			
10-3		None	—	0.22	0.34	0.22		0.002	0.00048	0.0019			
11-1	9	Cb-V Alloy	0.59	0.25	0.43	0.15	0.011	0.006					
11-2	9	Cb-V Alloy	1.79	0.23	0.42	0.18	0.022	0.026					
11-3		None	—	0.21	0.35	0.16	Nil	<0.002					
12-1	10	Cb-V-B Alloy	0.59	0.21	0.45	0.21	0.011	0.008	0.00036				
12-2	10	Cb-V-B Alloy	1.79	0.21	0.45	0.25	0.023	0.027	0.0011				
12-3		None	—	0.23	0.41	0.24	Nil	<0.002	0.00020				
13-1	11	Cb-V-B Alloy	0.88	0.20	0.37	0.20	0.011	0.008	0.0023				
13-2	11	Cb-V-B Alloy	2.64	0.20	0.34	0.22	0.028	0.021	0.0053				
13-3		None	—	0.21	0.32	0.22	Nil	<0.002	0.0002				
15		None	—	0.21	0.39	0.18	Nil	Nil					
15-A		None	—	0.20	0.49	0.25	Nil	Nil					
16	1	FeCb	1.32	0.20	0.42	0.23	0.022	Nil					
17	1	FeCb	2.64	0.21	0.43	0.24	0.05	Nil					
18	3	FeV	1.14	0.21	0.47	0.26	Nil	0.029					
19	3	FeV	2.28	0.22	0.45	0.22	Nil	0.055					

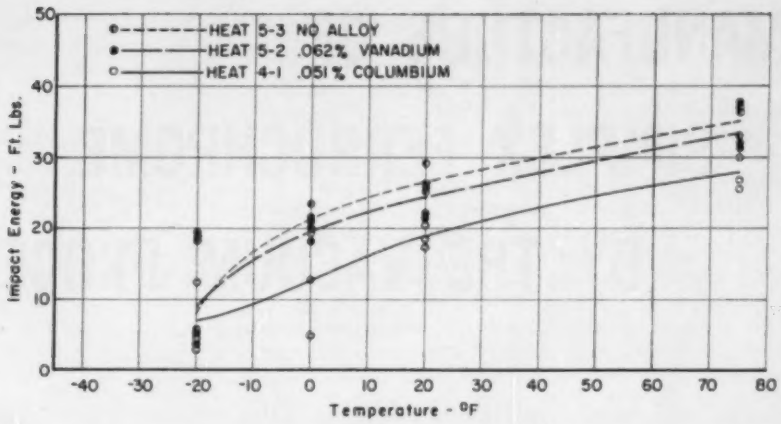

Fig. 3—Impact values from key-hole Charpy specimens (as-forged steels).

graphic examination failed to show a consistent microstructure difference between steels with increased yield strength and their respective base steels.

A comparison of the hot-rolled heats 15 through 19, shown in the series of photomicrographs as Figs. 1 and 2, shows some structural differences of the carbide believed to be the result of the alloying additions. It should be noted that the 0.022 pct Cb addition, heat 16, forms a semi-continuous carbide envelope at the ferrite grain boundaries. This grain boundary condition probably accounts for the decreased impact resistance of this steel at room and low temperatures.

Conclusions

Small additions of between 0.02 pct and 0.06 pct of either columbium, vanadium, or combinations of these elements, appreciably increased the yield strength of silicon-killed AISI 1020 steel in the hot forged or rolled conditions. No additional improvement in hot-rolled properties resulted from boron and/or titanium additions. Single alloy additions were as effective as combinations.

Tensile strengths of forged steels showed some increases, but results were inconsistent. All rolled steels showed increased tensile strengths with either vanadium or columbium additions. This suggests the importance of controlled hot finishing conditions. Vanadium treated steels in the hot-rolled condition showed from 5 to 8.6 pct higher elongation than similar additions of columbium.

Low temperature impact values were higher and the transition temperature lower for vanadium treated in comparison with columbium treated heats. This apparent difference in impact (and tensile ductility) may be associated with the partial carbide grain boundary condition observed in the microstructures of the columbium-containing steels.

The as-forged or rolled grain size of the steels containing columbium, vanadium, or combinations of these elements, was significantly smaller than the base steels. Columbium appeared to give the finest grain size.

No correlation existed between end quench hardenability values and improvement of yield strength in the hot forged or rolled bar product. Columbium was the only element that decreased hardenability.

Efficiency of alloy recovery from melting averaged 82.5 pct for columbium and 91.9 pct for vanadium.

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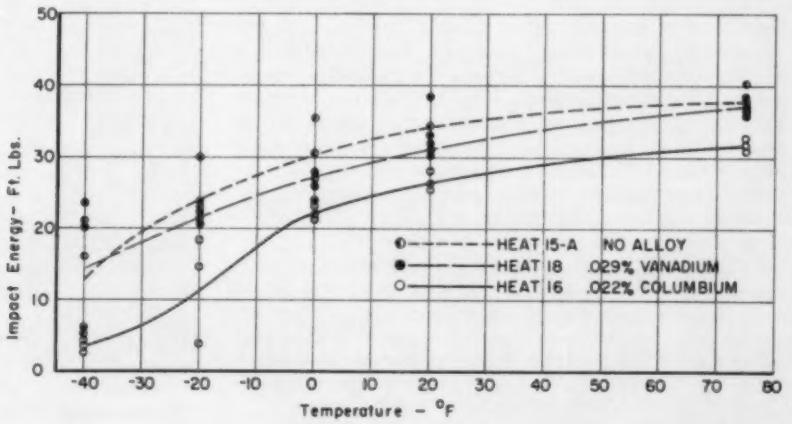

Fig. 4—Impact values from key-hole Charpy specimens (as-rolled steels).

MANUFACTURE OF SIMPLEX FERROCHROME BY THE VACUUM PROCESS

A vacuum process and manufacturing facilities for the production of low-carbon ferrochrome are described. The vacuum process is based on the solid-state reaction between the carbon in finely-ground, high-carbon ferrochrome and oxygen-bearing materials to evolve carbon monoxide.

by C. G. Chadwick

Simplex low-carbon ferrochrome is the result of many years of development by the Union Carbide Metals Co. of a vacuum process for producing low-carbon ferrochrome from high-carbon ferrochrome. Initial investigation of the process was started in 1943.[1] As the investigation progressed, it became apparent that existing vacuum furnaces were not suitable for the process as commercially envisaged. This led to the development of a new vacuum furnace and then to the construction and operation of a complete pilot plant wherein the multiplicity of problems inherent in any such new approach to ferroalloy manufacture were studied. With a background of several years' experience in the pilot operation, the decision was made to construct the commercial plant.

The production of low-carbon ferrochrome by electric furnace smelting generally involves reducing chrome ore with carbon to form a high-carbon ferro-chrome, displacing the carbon with silicon to form a ferrochrome-silicon—or reducing chrome ore and quartzite with carbon to form a ferrochrome-silicon directly—and then removing the silicon by refining with chrome ore and lime. In each step the necessary reactions are carried out in the liquid state at very high temperatures.

The present vacuum process for low-carbon ferrochrome is based on the solid-state reaction between the carbon in high-carbon ferrochrome and oxygen-bearing materials to evolve carbon monoxide. This is accomplished by heating an intimate mixture of finely-ground, high-carbon ferrochrome and oxidant in vacuum to temperatures below their melting points. To illustrate the type of reaction involved, chromium carbide is oxidized by chromic oxide in accordance with the following:

$$5\ Cr_2O_3 + 27\ Cr_3C_2 = 13\ Cr_7C_3 + 15\ CO \quad \text{(Ref. 2)}$$
$$5\ Cr_2O_3 + 14\ Cr_7C_3 = 27\ Cr_4C + 15\ CO$$
$$Cr_2O_3 + 3\ Cr_4C = 14\ Cr + 3\ CO$$

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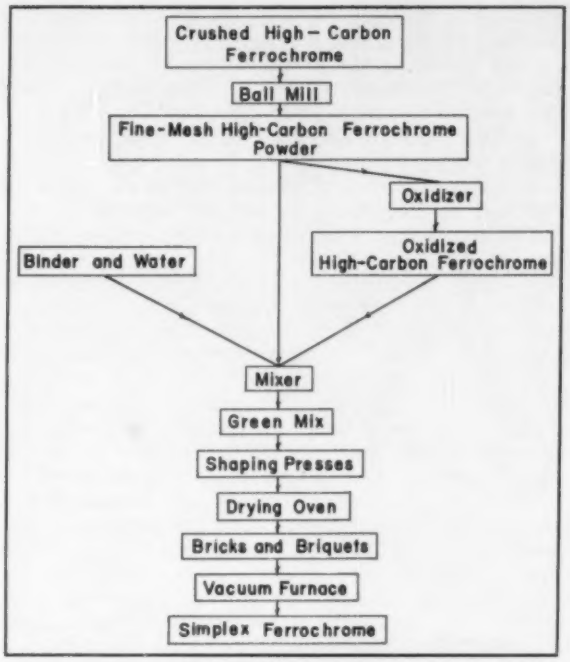
While these reactions will proceed in the order shown at atmospheric pressure, the required temperatures are excessively high. At lower temperatures, the carbon monoxide pressure becomes subatmospheric. By continuous removal of this gas in a vacuum system at sufficiently low pressure, the reactions can be completed at a temperature which does not exceed the melting point of either reactants or product. Maximum area of surface contact for the solid-state reaction is provided by intimate mixture of the milled high-carbon ferrochrome and the oxidant.

Flowsheet

The general flowsheet of the vacuum process, using oxidized ferrochrome as oxidant for the Simplex reaction, is shown in an accompanying figure. Crushed high-carbon ferrochrome is delivered to storage bins from which the ferrochrome is fed at a controlled rate to a battery of ball mills and milled in closed-circuit grinding to a very fine particle size. The discharge from the mills is mechanically classified, the oversize returned to the mills, and the fine size conveyed to large storage bins. Part of the milled high-carbon ferrochrome is oxidized by a special process to provide the oxidant. When silica is employed as the oxidant in Simplex ferrochrome manufacture, a high-purity silica sand is milled in a separate milling circuit.

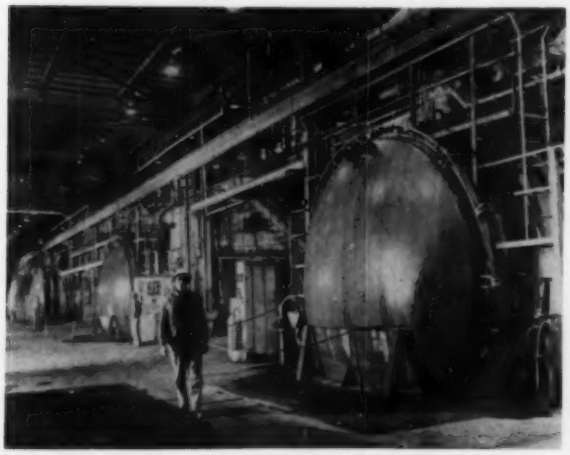
In the initial studies of the process, several other metal oxidants in admixture with high-carbon ferrochrome were investigated. All gave effective decarburization. However, some were objectionable from the standpoint of volatility of the metal, others were considered unsuitable by reason of economics. To meet the steelmakers' needs for a low-silicon product to supplement the high-silicon product made with silica as the oxidant, a high-grade chrome ore was used for a time in the commercial process. However, continued improvement of the process has resulted in the substitution of oxidized high-carbon ferrochrome for chrome ore oxidant.

Proportions of high-carbon ferrochrome and either silica or oxidized high-carbon ferrochrome



Major steps in the production of Simplex ferrochrome using oxidized high-carbon ferrochrome as oxidant.

in the ratio to ensure decarburization are weighed automatically and fed to a muller-type mixer where water and binder are added. After a predetermined mixing cycle, the wetted mixture is formed into either of two convenient shapes. For the briquetted product, which measures approximately 2 x 2 x 1⅛ in. and weighs about 0.3 lb., the mixture is fed to a roll-type briquetting press. For the larger brick product shapes, which weigh approximately 22 lb and measure 8 x 4½ x 4 in., the mixture is compacted on a special press. Both the briquets and brick are strong enough in the green state for ordinary handling, but to impart sufficient strength to retain their shape during charging to the furnace, the green compacts are conveyed automatically through a gas-fired oven. After drying, the hardened shapes are mechanically loaded onto a hearth car which is in turn charged to the vacuum furnace.



One bank of four vacuum furnaces during operation.

Simplex vacuum furnace

The vacuum furnace consists of a reinforced cylindrical steel shell 140 ft in length and 15 ft in diameter. The furnace shell rests in steel saddles mounted on concrete pillars. The entire furnace structure is set in a concrete-lined pit which acts as a collection basin for the cooling water used during the furnace operation. The upper half of the inside of the furnace shell is lined with high-temperature insulating brick. The lower half of the furnace is unlined but is protected by the refractory of the hearth car. A single unit refractory-topped hearth car 120 ft long rides on a set of rails in the bottom of the furnace. To protect the ends of the furnace from overheating, refractory baffles, which are mounted on separate trucks, are positioned at each end of the furnace. Tight closure is provided by a vacuum seal at the removable head of the furnace.

There are a total of eight vacuum furnaces in the Marietta plant. These are arranged in opposite banks of four each, with the removable head of the furnace facing the corresponding head of the furnace in the opposite bank. Rolling of the hearth car in and out of the furnace is accomplished by a transfer car, which carries the hearth car and which laterally traverses the area between the two banks of furnaces. The transfer car is equipped with a chain drive and ram which engage the underside of the hearth car to roll it in and out of the furnace. Vacuum outlets are connected to a manifold running lengthwise of the bottom of the furnace. This manifold is in turn valved to a steam ejector system.

The furnace is heated by horizontal graphite resistors suspended from the top of the furnace shell through water-cooled copper terminals. The graphite resistors are alternately energized and de-energized by contractors to maintain desired temperature in the furnace. Temperature is controlled automatically during the heating cycle by radiation pyrometers sighting on the top of the charge through a series of sight ports along the length of the furnace. Optical pyrometer readings are also taken through auxiliary sight ports.

Furnace control room

Each bank of four furnaces has its own central control room. The instrumentation in each control room includes temperature recorders for measuring both furnace and water temperatures during the furnace heating and cooling cycle, vacuum gauges and recorders, and argon flow meters. Also included in the control room are transformer tap changers for controlling voltage to the furnace heating elements. An alarm system working in conjunction with several of the gauges gives warning of low steam pressure or excessive temperature or pressure during operation of the furnace.

Vacuum system

There are two five-stage steam jet ejectors on each furnace. These are designed to maintain an absolute pressure of less than 3 mm Hg in the furnace during the heating cycle. The ejector system is, in general, the same as that now being used in the steel industry for ladle and stream degassing. Inter-condensers are provided to remove the large condensable load carried over from the ejector

stages preceding the inter-condensers. A *hogging* ejector provides quick evacuation in the initial stages of the furnace heating cycle.

During the furnace heating cycle, the ejector sets are operated as four-stage units when gas load from the furnace is high and as five-stage units during the period of low gas load. The first-stage ejector is provided with a by-pass line so that when the ejector system is operated as a four-stage unit, which means that no steam is going through the first stage, the gas flow is via the by-pass line to the succeeding ejector stages.

Each five-stage unit can be isolated from the furnace in the event of any operational difficulties in the ejector system. Should steam pressure drop to below the designed pressure for the ejector system, the steam flow to the ejectors is automatically shut off. In this event, a water seal through the barometric leg prevents a surge of air into the furnace before the vacuum valves to the furnace can be closed, and the furnace is thus isolated from the vacuum system.

Operation of the furnace

Before the furnace is charged, it is cleaned of any condensate collected from the preceding run. The hearth car containing the stacked charge is then rolled into the furnace, the head car positioned in the furnace, and the cover set in place. The ejectors are started in the normal manner, i.e. the last or low-vacuum stage first and then succeeding stages, and the furnace is evacuated to less than 2 mm absolute pressure. To check whether the furnace is sufficiently vacuum tight for operation, it is isolated from the ejector system by closing the main valve to the furnace, and the leak rate to the furnace is determined. If the rate is satisfactory, the furnace is opened to the ejector system, and power is applied to the furnace.

The furnace is heated at a programmed rate until the maximum operating temperature, which is about 2500°F, is attained. If the furnace is heated at too fast a rate, fusion of the charge may occur.[3] This is because as decarburization proceeds the high-carbon ferrochrome passes through a eutectic composition at about 2.75 pct C which has a melting point close to 2300°F. With continued decarburization the temperature of the solidus curve rises sharply, and it is then possible to increase the furnace temperature without danger of melting. Throughout the power cycle, on-off contactors control power to the graphite resistor heating elements to maintain the desired temperature in the furnace. In normal practice, the furnace is held at the maximum temperature until decarburization of the charge is complete.

Hearth car loaded with ferrochrome brick product being discharged from furnace after vacuum processing.

Temperature control during the power cycle is checked at frequent intervals by sighting on the top of the charge with an optical pyrometer. While temperature is automatically controlled with radiation-type pyrometers, visual checking safeguards against falsely-indicated, low-temperature readings due to clouding of the sight glass or improper alignment of the radiation sighting instrument.

When the reaction approaches the end point, as indicated by reduction in the rate of gas evolution to a predetermined level, the power is shut off. With the power off, the furnace is isolated from the ejector system, flooded to a slight positive pressure with inert gas such as argon, and cooled. When the furnace is sufficiently cool for unloading, the head cover and refractory baffle are removed from the furnace. The hearth car is then rolled from the furnace, and transferred to an unloading area where the product is carefully sampled and mechanically unloaded into skips or bins.

Simplex furnace product

The product as it emerges from the furnace is in shippable form and no cleaning or crushing operations are required. The final product from the Simplex furnace operation is made to a maximum carbon specification of 0.01 or 0.025 pct C. Depending on the oxidant employed, the product made to the 0.01 pct C specification has one of the following typical analyses:

Oxidant	Pct C	Pct Cr	Pct Si
Silica	0.008	65.5	6.5
Oxidized FeCr	0.008	69.5	1.10

Because the final product is the result of a solid-state reaction, small amounts of non-metallics are present.

Physically, the product is the same shape as the furnace charge. However, its weight has decreased due to removal of carbon as carbon monoxide during furnacing, and it is considerably smaller in size because of the shrinkage and densification which occur during the furnace operation.

Because of its method of manufacture, the low-carbon ferrochrome made by the vacuum process has certain unique characteristics as compared with the melted and cast alloy. Its porosity, with a density only slightly less than that of the cast alloy, contributes to its faster solution rate when added to a steel bath. Finally, it is characterized by an extremely low-carbon content which can be consistently met in manufacture by the vacuum process.

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THE MINERAL RESEARCH PROGRAM OF THE BUREAU OF MINES

This article is the first of a series describing the Bureau of Mines research program for minerals, excluding the mineral fuels. Mr. Merrill describes the processes of planning, budgeting, and directing metallurgical and mining research. In a second article to be published in the December issue, H. G. Iverson, chief, Branch of Metallurgy Research, Division of Minerals, will cover the Bureau's metallurgical research program and its management. In a third article to appear in the January issue, Frank D. Lamb, research director, College Park Metallurgy Research Center, Division of Minerals, will set forth the operation of a typical metallurgy research center.

by Charles W. Merrill

The minerals research program of the Bureau of Mines embraces the mining and metallurgical problems of some 80 metals and non-metals excluding the mineral fuels. It requires the energies and talents of about 1400 persons, almost half of whom are professionally trained in the physical sciences or engineering. Of approximately $13 million appropriated to the Bureau for minerals programs in Fiscal Year 1962, 76 pct has been allotted to technologic research and 24 pct to resources examination and appraisal. In addition, almost $2 million will be made available to the Bureau for minerals research from other Government sources and from private organizations that wish to utilize Bureau experience and capabilities in cooperative studies.

Research programming is organized essentially on a commodity basis and is carried on by a headquarters staff of physical scientists assigned to specific commodities and identified organizationally as commodity specialists. The research itself is carried out on a functional basis by a staff of engineers, scientists, and technologists under the local supervision of research directors, working in research centers and laboratories or out of field offices scattered strategically throughout the Country. Each commodity program is designed to fit into a coordinated approach to the national mineral-supply problem, and to extend utilization through knowledge of mineral characteristics. Research projects are placed in one of two main groupings: 1) metallurgical research, conducted at metallurgy research centers or laboratories and, 2) mining research, performed at mining research centers, laboratories, or offices.

The Bureau's work on minerals is carried on in an atmosphere paralleling research elsewhere, but with some important differences:

1) The research program must be within the authority of the Bureau of Mines as set forth in its Organic Act;
2) Principal financing of the program is with funds recommended by the President in his budget and appropriated by the Congress annually;
3) The work must be accomplished by a staff recruited and employed, under the exacting regulations of the United States Civil Service Commission; and
4) Perhaps most important of all, the results of research are public property and, consequently, are widely published and are under constant general scrutiny.

The Bureau's Organic Act of 1910 authorizes and directs it ". . . to make diligent investigation

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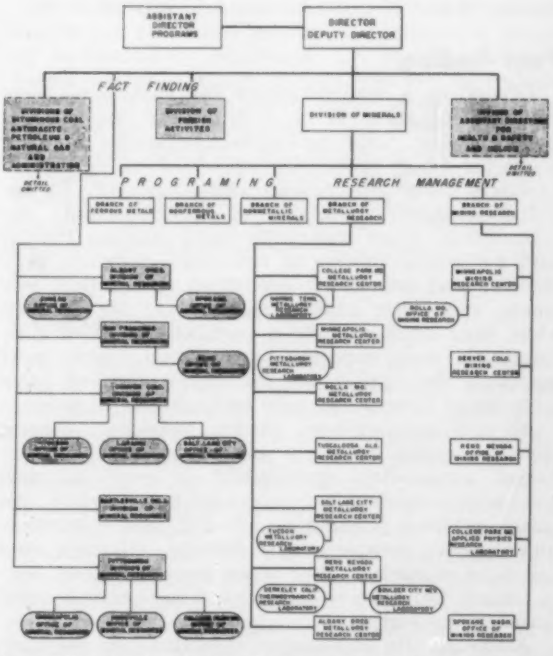


Organization of mineral research program of the Bureau of Mines.

of the methods of mining, . . . the treatment of ores and other mineral substances, the use of explosives and electricity, . . . and other inquiries and technologic investigations, pertinent to said industries . . .". The breadth of this authorizing language places little, if any, limitation on the fields of mining and metallurgical research permitted the Bureau. There are, however, limitations imposed by administrative rules that mark out and assign certain areas to other Federally-supported research institutions, such as the National Bureau of Standards and the Atomic Energy Commission, in order to minimize duplication of effort. Moreover, the Bureau's staff continually reviews reports on minerals research conducted elsewhere, particularly in private laboratories, so as to avoid unnecessarily duplicating results that would become available to the public.

The scope of legal authority, although affording great freedom in planning and programming, poses difficulties when appropriated funds are sought from the Congress. The Bureau is confronted each year with the task of constructing a budget that reflects national needs, is appropriate to its own research capabilities, and is couched in language both understandable and logical to high officials in the Administration and in the Congress, most of whom have only a general acquaintance with mineral technology and science.

Therefore, the Bureau begins its program development with the fundamental assumption that its mission is to help assure an adequate, dependable, and continuing supply of minerals to meet the needs of an expanding population, a rising standard of living, and the national security, produced under conditions minimizing hazards to the health and safety of workers in the mineral industries. The problems inherent in current and foreseeable demand are evaluated, and the potentialities of mining- and metallurgical-research approaches for assuring adequate supplies of each commodity are appraised. The budget finally proposed to the Congress is derived from this comprehensive and intensive study of all available information.

Fact finding

Obviously, a comprehensive and continuing fact-finding operation is a prerequisite to rational programming. This fact-gathering is the starting point for every commodity specialist on the Headquarters programming and managing staff. To develop realistic projections of mineral-supply requirements, these specialists must conduct timely, and extensive surveys of resources, reserves, productive and processing capacities, production, imports, and other related factors. On the demand side, they must compile a parallel record of consumption and exports. In addition, they must appraise the impact on the supply-demand-price balance of factors like new technologies in production and consumption, tariffs, subsidies, quotas, noncommercial stockpile programs, and international commodity agreements, as well as such pervasive considerations as population increase, the gross national product trend, and major international policy reorientations. Finally, all these data must be related so that what emerges is not only a record but also a series of trends which form bases for projections.

Although the commodity specialists on the program staff collect, arrange, and interpret this mass of information primarily for use in formulating and guiding the technical research program, they also provide, as a byproduct, a major fact-finding service. This service reaches the public primarily in the form of interpretative reports published annually in the Bureau's *Minerals Yearbook*, in some 400 *Mineral Market Surveys* (mainly statistical), in definitive *Materials Surveys* that present detailed information on individual commodities, in other Bureau reports published mostly as Information Circulars, and as trade journal articles and addresses.

Data on domestic reserves and mine production are collected by Mineral Resources Offices in the field. Likewise, most information on foreign production, consumption, and trade is compiled by others than the programming group. However, the commodity specialists do collect domestic mineral-consumption data on a large scale by direct canvassing of industry. Each specialist acts as a focal point in the Bureau for supplying information and advice on his commodity. Thus, in addition to his programming duties and responsibilities for reviewing technical manuscripts dealing with his commodities, the commodity specialist conducts an information service by writing reports, answering queries through correspondence and personal interviews, and by acting as an interagency adviser in the area of his specialty.

Programming and budget

The Bureau's research-programming problem is normally more complex than that encountered by most private research groups in that the whole mineral field must be considered.

Although the Bureau of Mines finds that the most effective rationale for its programming is based on the commodity approach, nevertheless it finds that the program must be carried out on a functional basis. Laboratories specialize in technologies, and the engineers, scientists, and technologists who work in them are even more specialized functionally. Therefore, the Bureau must translate the commodity programs it develops into the technical-research operations it manages. The following paragraphs describe the methods by which the Bureau of Mines carries out: 1) program formulation, budget construction, and preparation of project authorizations for the research establishments, all of which operate outside of Washington, D. C.; 2) management of the research carried on in research centers and laboratories; and 3) technical review and preparation for publication of the results of mining and metallurgical research.

Program formulation for the Bureau of Mines as a whole is coordinated under the guidance of the Assistant Director—Programs, whose office is primarily responsible for advising the Director, in cooperation with all Headquarters divisions, on what programs might be most profitably pursued for maximum national benefit.

In addition to meeting the basic national-supply problem, the Bureau's program has a broad purpose which can be summarized as follows: 1) Appraise the United States' mineral position to provide Government and private industry with facts needed for wise direction of their respective activities; 2) Develop technologies for exploiting currently submarginal mineral resources that will be required to maintain an adequate, dependable, and continuing supply of mineral raw materials; 3) Find new or

wider uses for abundant mineral resources to relieve the drain on materials in short supply, and promote the establishment of new industries based on the use of plentiful minerals; 4) Develop substitutes for scarce minerals and metals to relieve strategic dependence on overseas sources and to keep industrial and social progress from being handicapped by raw material deficiencies; 5) Conserve the Nation's mineral resources by efficient exploitation and wise use, including reuse of reclaimable scrap materials; and 6) Search among mineral commodities and products for properties and combinations of properties that will afford useful materials to designers faced with problems in building structures and fabricating devices for the new and exacting conditions of the Space Age.

The commodity program statement itself opens with a background section giving information about the commodity. This is followed by brief sections on Outlook, Problems, Avenues of Attack on Problems, and finally the Program for the Bureau of Mines. (It is noteworthy that the first minerals program manual created so much interest among outside critical reviewers that the Bureau was prevailed upon to publish the basic information on mineral commodities as *Bulletin 556–Mineral Facts and Problems in 1956,* now in its second edition under the same title as Bulletin 585.)

These commodity program statements which are updated systematically are distributed in the Bureau and project proposals are invited to carry out the objectives as set forth. Proposals are relatively specific and normally deal with a single technical avenue of attack on a particular commodity problem. Most proposals originate in the research centers and laboratories. They are evaluated to determine if (1) they are within the Bureau's program and (2) what contribution they are likely to make toward the solution of a commodity problem.

The next stage is the selection of proposals for the formulation of a budget. Such selection is not a simple matter. For example, the question has been raised as to the practicality of comparing widely dissimilar research proposals. How can the worth of research on support of excessively heavy ground in the lead-zinc-silver mines of the Coeur d'Alenes be compared with research on extraction of copper from oxidized Arizona ores by segregation and flotation? The question before the Bureau is not how it will make a precise evaluation of the national interest in these two proposals but rather, knowing it must make a decision in recommending research financing between them, what will be its rationale for justifying its position. The proposed budget emerges as a balanced evaluation of commodity need, functional proposals, and research capabilities. It is reviewed at various levels of Government in the Bureau, the Department of the Interior, the Bureau of the Budget (representing the President in balancing the various activities of the Administrative branch), and the Congress, which includes separate committees of the House and Senate, and finally floor action by each of the two branches. After reconciling differences, the Congress sends an approved appropriation bill to the President for signature.

Authorization of research work

When the funds for a new year's work become available, authorizations are written describing the research objectives, consistent with the proposals on which they are based and modified by statements made during the program and budget approval processes. A research authorization conforms to the budget structure and confines itself to work for a single research center.

Following an opening paragraph which provides for uniform operational directions, the body of an authorization is made up of separate paragraphs, each describing a research objective. The language in these paragraphs indicates their relative importance, but the only mention of money is a single amount which is the sum authorized for all the components. The division of the funds among the separate research objectives is entirely in the hands of the responsible research director, acting under the guidance contained in the paragraphs and with due regard for operating conditions.

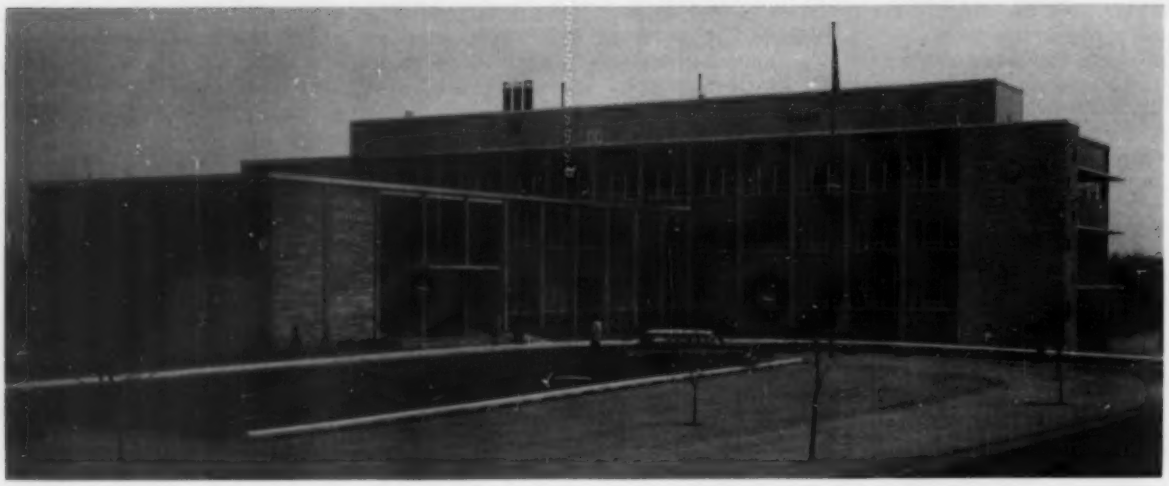
On receiving their authorizations, the research directors prepare work schedules outlining their proposed operating procedures. The preparation of the work schedules by those who will direct the work promotes efficiency by permitting full weight being given to local operating conditions. The work schedules are binding, except that they may be revised by the research directors at any time, provided the revision is within the limits of the authorization and is promptly reported to Headquarters. Thus, research objectives are set firmly by the program planners and managers at Headquarters, yet operational flexibility is preserved throughout the budget year in the hands of local research directors.

As research proceeds, progress is reported periodically, usually on a quarterly basis, with intervening monthly reports on special developments. At the end of the fiscal year a summary report, reviewing and analyzing the year's accomplishment and recommending work for the future, is made for each research project. Research centers also are visited periodically by members of the Headquarters technical staff who are following the operations.

The principal products of Bureau of Mines research are published reports. As important phases of research are completed, the results are published normally in the Bureau's *Report of Investigations* and *Bulletin* series, and also in articles for technical journals, speeches, and other vehicles of publication. However, all substantial research findings are published as promptly as possible in some Bureau series. This policy assures indexing and library custodianship so that the public will have easy and permanent access to the Bureau's research findings.

Summary

The Bureau of Mines studies the mineral research problem from beginning to end. First, the problem itself must be defined and the natural resources to be drawn upon must be delineated. Then the many disciplines of science, technology, and engineering must be enlisted in the effort. Some 14 research establishments valued at $17 million must be equipped and maintained. A balanced program must be formulated and presented intelligibly and convincingly to laymen who determine the funds to be made available. Finally, the program itself must be managed in such a way as to produce positive and valuable results in terms of the national economy and the national security.



BUREAU OF MINES' NEWEST RESEARCH CENTER — MINNEAPOLIS —

The new $2.5 million research center near Minneapolis, Minn., provides modern facilities for the US Bureau of Mines to continue a wide range of mining and metallurgical research and industry fact-gathering activities which it has carried out in that area for some 45 years.

The research center consists of three new structures—the office, laboratory, and pilot-plant building; the sample preparation building; and the equipment storage building—and two structures built several years ago—the mining research building and the core storage warehouse. The new buildings which provide 93,000 sq ft of floor space, are designed and equipped to conduct a wide range of mineral and metal investigations.

Attractively fabricated of stone, colored brick and tile, with ample use of bright aluminum and glass, the main building incorporated the best design features of other Bureau research centers and most modern industrial laboratories. The cross shape of the building permits the separation yet proximity, of office space and laboratories and of laboratories and the pilot plant.

The laboratories are equipped with the most modern instruments and apparatus. Many items, such as oscilloscopes and X-ray diffraction instruments, are standard laboratory items, but other equipment needed for research work is built or specially assembled by the technical staffs. The roster of personnel represents a wide variety of talent and scientific skills including chemists, physicists, geologists, metallurgists, and mining engineers. The Center comprises three divisions: mining research, metallurgy research, and mineral resources. In this article we shall discuss only the second of these.

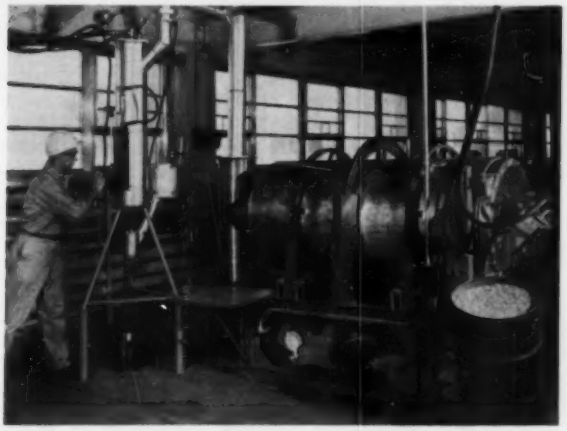
Metallurgical research

Since the programs of metallurgical research conducted by the Bureau are nation-wide in scope, the Metallurgy Research Center at Minneapolis is prepared to undertake the solution of a variety of problems relating to domestic minerals regardless of their location. However, because of the Center's proximity to the iron ores of the Lake Superior Region, it is only fitting that it should give special attention at this time to the extensive deposits of taconites and semi-taconites. In their beneficiation two avenues of research have been pursued: a) reductive roasting followed by magnetic separation, and b) flotation.

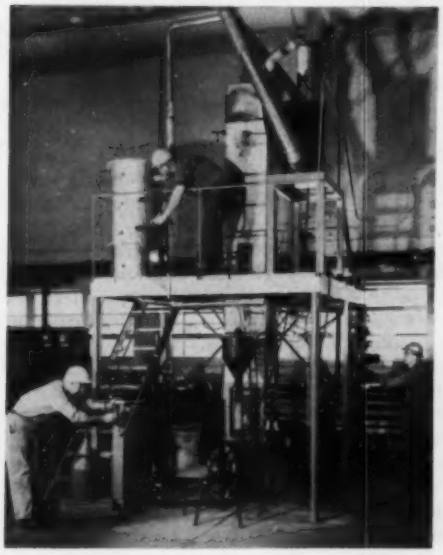
Iron

The present emphasis at the center is on the second of these, flotation. In the Bureau's silica flotation process, three basic reagents are required to prepare the surface of the particles: sodium hydroxide to control the pH, gum dextrine to depress the iron, and a calcium salt which is preferentially absorbed on the silica to permit collection by fatty acids. This technique of floating the silica results in high iron recoveries, although reagents costs are higher than for floating the iron. A detailed description of this flotation technique is scheduled for a forthcoming issue of the JOURNAL OF METALS. At

Above, Leaching experiments conducted on low-grade Mn ores at the new research center.



Above, Making a test with a combustion evaporator as part of the Bureau's program to utilize the vast low-grade manganese reserves of the Cuyuna Range of Minnesota. Below, A fluidized bed reactor is among the equipment being used for sulfatizing Cuyuna ore.



present the pilot plant used for the continuous testing of this method is playing the dual role of confirming laboratory tests and providing sufficient concentrates for research on pelletizing and pre-reducing.

A line of research which has grown out of the Center's earlier work in pellet hardening is that of pre-reduction. Initial results of this work were described in an article by Hansen, Melcher, and Fine which appeared on pp. 314-315 of the April 1961 issue of JOURNAL OF METALS. Many variations in the technique have been tried, but the emphasis has been on reducing the iron oxides only to such an extent as would appear to be economic in plant operations. Laboratory findings are now being confirmed by running tests in an experimental gas-fired rotary kiln. Later, tests will be made with these pre-reduced pellets in the Bureau's experimental blast furnace at Bruceton, Pa. (see JOURNAL OF METALS, May 1960, pp. 406-409).

Manganese

Another area of experimental work at Minneapolis is that of the recovery of manganese from domestic ores. The Cuyuna Range of Minnesota contains one of the largest reserves of manganese in the United States, but these are primarily iron ores, containing 25 to 30 pct Fe and only 3 to 10 pct Mn. Earlier studies dwelt almost wholly on recovery of the manganese, but the Bureau now has a different approach: the recovery of both the iron and the manganese. Direct-iron reduction techniques are being applied to convert the iron oxides to metal, while manganese remains as an oxide. The metallic iron is then removed magnetically, and the manganese can be readily recovered from the non-magnetic fraction by dilute acid leaching. This line of research is just beginning, but the prospects of favorable results appear to be good.

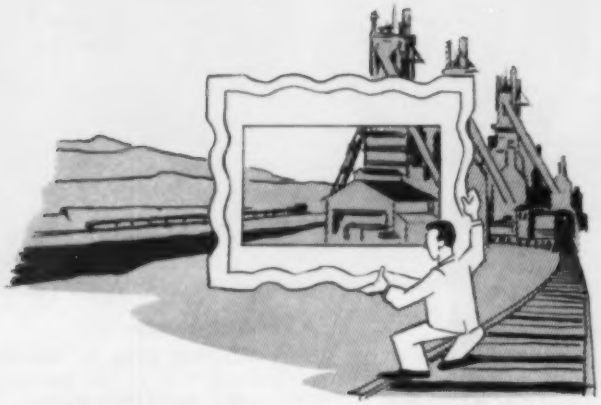
Another approach to a practical method of extracting manganese—sulfatizing—is suggested by the fact that the Cuyuna Range also contains large tonnages of low-grade sulfur minerals. Small-scale tests in the laboratory show that more than 85 pct of the manganese in the ore is recoverable by sulfatizing. Individual steps in the process have been tried on a pilot-plant scale, and products containing over 50 pct Mn have resulted. A shaft furnace or a fluidized bed is used for sulfatizing the ore. Water is added to the furnace product, thereby effecting a separation of the soluble manganese sulfate and the insoluble iron oxides. The solution is passed through an evaporator and a furnace to produce manganese dioxide and a sulfur dioxide gas which is recycled to the sulfatizing furnace. In addition to the Cuyuna ores, sulfatizing experiments will be conducted on laterite nickel from Puerto Rico and the Philippines with a view toward producing a nickel electrolyte for electrolytic refining. Chrome ores may also present a possibility.

And

We have mentioned only a few of the major metallurgical research projects of the Bureau of Mines Minneapolis Research Center, but a great deal of other work is being undertaken, not to mention a myriad of programs in the mining side. The new building is the most modern of its type among the Bureau's national chain of research centers and is designed to house a large number of scientific projects.

FWS

IRON ORE:



THE BIG PICTURE

by E. H. Rose

It must be evident to almost everyone by now that a massive transformation is occurring in our iron ore economy. Its equal has been seen only once before in the entire history of the North American steel industry, and not even once before within the personal memory of anyone now engaged in it. The lone precedent was the beginning of ore shipments from the Mesabi Range in October, 1892 which was before anyone still short of normal retirement age had been born. No younger observer, in the steel industry or in any other, has ever known anything else than that the Lake Superior region—in which the Mesabi is the giant—has supplied all but a small fraction of total North American blast furnace ore for the use of three generations of steelmakers.

Directly or indirectly, it was the discovery of the Mesabi which created most of the prime and satellite companies that have since come to prominence in the various ore-consuming phases, and it was the same discovery that had broader effects on the entire spectrum of their technologies than any other single event that has ever happened since, although the advent of byproduct coke is a close runnerup. It affected every sector of the national economy and was a keystone in making our standard of living what it is today. In terms of geographic source and overall chemical grade of ore, the period now receding might be called the Era of Constancy, although the silica content was slowly edging upward.

Now, almost as suddenly, the same thing is happening all over again for the first time in three generations—not all in one place but certainly on an equally magnificent scale. As before, the ores now coming into use were scarcely known to exist 15 years earlier, but like them, these new ores are indisputably able to meet U.S. requirements for many years to come. Apart from sheer size, they are capable of yielding an average shipping product approximately one-fifth higher in iron tenor than the historic standard.

Tables I, II, and III show sources, tonnages, and grades. Anyone may split hairs over the 1970 figures, but not those of 1960 which are the recorded actuality, nor of 1965 for which the enormous capital investments required have already been committed. It is the spectacular improvement in chemical quality which necessarily denotes the impact upon all areas of use technology, given the basic circumstance that the ore reserves required to sustain this grade have already been proved.

Thus quality combines with quantity to underscore the statement that no one now active in the steel industry has witnessed a transformation of this magnitude within his professional lifetime. This is particularly apparent when looking over the record of grade in past years. In no single year from 1910 to 1958, according to the American Iron Ore Association, did the average grade of all iron ore used in

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North American blast furnaces exceed 52 pct Fe natural, with the merest whisker of an exception in the two depression years of 1921 and 1932. Such is the about-face that in the near future anything under 60 pct Fe will face competition previously unknown. The tables make it clear that a grade of over 60 pct Fe can be maintained for years to come, even at the highest annual consumption rate yet experienced in North America, and with Golden Rule deference to the exploding needs and wants of the rest of the world.

The swiftness of the change can be inferred from the fact that the earliest of the new properties did not come into commercial production until 1954. Seen in perspective, the ore discoveries, though widely dispersed, may be regarded as a single drama, like the acts and scenes in a Shakespearean play. The technical press has chronicled the individual events: the discovery of Cerro Bolivar in Venezuela on April 4, 1947 (the only major ore discovery since the California gold rush to be dated to the day) but from which commercial shipments did not reach the United States until 1954; the Labrador Trough, with direct shipping ore also first moving in 1954 without early appreciation of its fabulous reserves of beneficiation grade from which 20 million annual tons of 65 pct Fe concentrate are scheduled by 1965; exploitation of the Minnesota magnetic taconites with multi-million ton production beginning in 1956; Ontario, only now beginning to add surprising muscle of its own; Peru, Brazil, and Chile adding multicolored pins to the hemispheric map; even Wyoming, Missouri, and Nevada beginning to light up where iron ore was not supposed to be; and finally Liberia, Sierra Leone, Mauretania, India, and other parts of the overseas world making iron ore headlines in bolder type each year.

The iron ore events of this decade are a matter of swiftly moving record, some of them undeniably heroic. In general, they are well enough known to the blast furnace operator, but from his comfortable seat in the stands he has been prone to look upon them as a spectator sport. Indeed, Owen R. Rice, who is to blast furnaces about what Ed Davis is to taconite, has recently pointed this out, somewhat ruefully. Suddenly, the agglomeration engineer and the blast furnace operator find themselves as the starting pitcher and catcher in the second game of an unexpected double-header. It all may be a spectator sport, but no longer so for them.

The statistical scoreboard of the first game is set up as Tables I and II. Each is divided into three categories: (a) capacity actually installed since 1953 and now in production; (b) under construction or definitely planned to be in production by 1965; (c) trade press predictions by 1970.

Over a billion dollars has been invested in the various taconite-type projects (not in Minnesota alone) which are now producing 20 million tons per year of 65 pct Fe pellets. Counting the exploration and development money, another billion has actually been committed in Quebec-Labrador for the production of another 20 million tons of concentrate of even better grade in three separate projects all scheduled for production by 1965 or earlier. Capital commitments already made or signified will bring in another 20 million annual tons of equally high-grade direct shipping ore from overseas.

Including other miscellaneous sources, all this adds up to the 86,650,000 annual tons shown for 1965, all of it + 60 pct Fe and record low silica. In gross tons, without allowance for better grade, this is the equivalent of almost exactly two-thirds of all iron ore used for all purposes in the US and Canada in the peak years of 1953 or 1957.

It would have been redundant to include data on ore reserves in Tables I and II, although the figures are available. In the mining business, capital investment actually made or committed is the sharpest possible criterion of ore reserves.

Agglomeration outlook

Sintering was not even invented until 1906, and not applied to iron ore until 1908. Today the total North American ferrous sinter capacity is 65 to 70 million net tons annually. In round numbers, the capital cost of a modern sinter plant is $10 per annual ton.

The bulk of Lake Superior iron ore has always been direct-shipping. First record of commercial washing or beneficiation, exclusive of mere crushing or screening, date from 1907 which coincides with the beginning of sintering.

By 1957, the total of all shipments of upgraded iron ore in the US and Canada (washed, jigged, heavy media, magnetic flotation, agglomerates, etc.) had reached 47 million gross tons a phenomenal increase but still less than half the total US and Canadian shipments of 118 million tons in that year.

Until perhaps 1940, when the pressures of World War II began to hurt, all agglomeration was looked upon as a necessary evil, which is to say, an expedient to permit use of — ¼-in. fines which otherwise took wing in the blast furnace, especially on inexorably increasing wind rates. Practically all agglomeration of fines was by the sintering process. About this time, the real virtues of sinter were finally recognized.

The hounds of progress were soon off in full cry. Within the decade, the *All-Sinter School* was born of the doctrine that even coarse ore should be crushed and sintered "whether it needs it or not" for the sake of better and more uniform physical structure, with a bonus for expelling volatiles. By 1953, full-dress blast furnace tests had been run which proved the new school to be thumpingly right in its prospectus. Hot metal production per furnace-day climbed steeply while coke rates dropped. New sintering plants sprang up, some of them at the very furnace plants where old line operators had been adamant in their belief that a blast furnace could never operate at higher than 25 pct sinter burden.

An historic turning point was reached in 1956 when the first taconite came to market in the form of pellets made by a radically new process. By 1958, it had become clear that such pellets had many virtues in the blast furnace, some of them new and unheralded. Hardly anyone paused to ponder that the pelletizing process was launched on a concentrate made from an ore requiring a 200-mesh grind for liberation and in which the iron mineral was almost entirely magnetite.

By the end of 1959, annual pellet production from these new and history-making iron ore concentrators had reached 18 million tons, all of it (with one exception) from fine magnetite. These pellets performed so well in the blast furnace that the conclusion-jumpers quickly reached a soul-

Table I. Summary of 60-69 pct Fe Direct Shipping Ore Imported by US from Overseas Sources*, Thousands Long Tons Per Year

Source	Actual		Expected		Possible	1965 Grade	
	1950	1955	1960	1965	1970	Pct Fe	Pct SiO_2
Algeria	500	20	—	—	—		
British West Africa	200	140	—	—	—		
Tunisia	120	—	—	—	—		
Liberia	0	900	1200	4000	6000	67.0	4.0
Sweden	2050	1200	200	200	200		
South America							
Brazil	700	1000	1700	7000	10,000	68.0	1.0
Chile	2000	2000	4000	6000	8000	62.0	5.0
Peru	—	1600	3000	4000	6000	60.5	7.0
Venezuela—Cerro Bolivar	—	7150	13,000	15,000	18,000	64.0	1.0
—El Pao	—	3500	3500	3500	3500	68.0	0.5
Total—South America	2700	15,250	25,200	35,500	45,500		
Grand Total	5570	17,510	26,600	39,700	51,700	65.0	2.9

* Includes open hearth lump.

satisfying judgment: even if the mining people finally should reach the bottom of the direct-shipping barrel and everything thereafter had to be concentrated from fine-ground beneficiation grade iron ore, there would never be a crisis in the agglomeration business that pelletizing could not take in stride. Hardly had the words been said when a surprise shook the agglomeration business to its very foundations.

It occurred in 1958 when the Labrador Trough showed its true colors. At the Duluth Symposium of that year, A. E. Moss, then chief geologist of the Iron Ore Company of Canada, ad-libbed an aside to his paper: "If we had known four years ago what we know now, we would have started off on a beneficiation basis in the first place." True to his confession, Labrador concentrate production will reach 20 million tons annually by 1965, and Table II duly notarizes his testimony in hindsight.

It was no responsibility of his that the Labrador ore was so much more granular than Minnesota taconite that most of it liberated cleanly at 20 mesh instead of 200 or that the iron mineral was hematite instead of magnetite. Off-hand these two differences might seem minor, but their combined effect on pelletizing was devastating. The heirs of Davis, the father of pelletizing, found themselves in roughly the same quandary as Messrs. Dwight and Lloyd might have experienced when they started baking *sinter cake* in 1906, if somebody had sneaked up and put rocks in their dough and turned the heat off the oven at the same time. A flash-back to the early development of the pelletizing process will make this clear:

Despite the scorn of the faithless and/or well-fed, Davis and his associates began in 1915 to seek means of utilizing low-grade taconite, against the inevitable day they rightly foresaw when Mesabi's cupboard would indeed be bare. Being in their right minds, they began on the eastern end of the Range where the iron mineral is in the form of magnetite and hence much easier to beneficiate because of its ready response to direct magnetic separation.

When their researches resulted in −200-mesh concentrate (because that is the way the Lord made the ore they were working with), they realized that their beneficiation effort would be fruitless without one more step because material so impalpable could not be sintered in the conventional sense by any then-known means.

In this unique howdy-do, the invention of pelletizing was mothered by necessity. That their pellets should behave in a superior manner in the blast furnace was a dividend these pioneers may have anticipated but vindication was still years away.

In modern pelletizing, the finely divided concentrate is mixed with a critically optimum amount of free moisture (about 10 pct) and 1 pct or so of a plasticizer, usually bentonite clay. When this mixture is discharged by conveyor or mechanical feeder upon an inclined and moving surface, such as an open-end revolving drum, and tumbled at appropriate speed, the mixture nucleates into *seed pellets* which grow in a manner often likened to that of a snowball rolling downhill over moist snow. By choice of moisture content, slope and speed of surface, balls may be *grown* to selected sizes. The diameter of pellets now preferred by blast furnace operators is ⅜ to ½ in.

The screen oversize in the form of dough-balls must have enough *green strength* to be conveyed to the hardening process. Sufficient heat is applied to cause intergrain growth and/or recrystallization. This temperature may be a little below that of conventional sintering, but not much. The indurated pellets must have enough physical strength not only to withstand degradation during transportation to the blast furnace but to retain that strength right down to the instant of reaching the actual smelting zone.

The heat-treating phase of the operation may be carried out in any one of a dozen different types of units, such as travelling grates, shaft furnaces, many kinds of kilns, and their various combinations.

Until the Quebec-Labrador concentrate came along, the only problem was choosing the most economic pelletizing process. But here, instead of being practically all minus 200 mesh like present feed to existing pelletizing plants, Labrador concentrate is nearly all on the coarse side of that magic line—and there are hundreds of millions of tons of such stuff ahead to deal with. Apart from being hematite instead of magnetite, all of the turmoil has been created by that single stumbling block of size structure. Following are the predicted

Table II. Summary of New Sources of High Grade Concentrate (+ 60 pct Fe), US and Canada

Property	Location	Year of First Production	Thousands Long Tons Per Year	Dry Basis Pct Fe	Dry Basis Pct SiO_2
CAPACITY NOW INSTALLED					
Extaca (U. S. Steel Experimental)	Minn.	1953	600	62.0	
Reserve Mining Co.	Minn.	1955	5000	62.5	
Cleveland-Cliffs Humboldt	Mich.	1955	300	63.5	
Cleveland-Cliffs Republic	Mich.	1955	600	63.5	
Marmarton (Bethlehem)	Ont.	1955	500	64.8	
International Nickel	Ont.	1957	150	68.0	
Erie Mining Co.	Minn.	1958	8000	62.5	
Hilton (Stelco)	Que.	1958	300	67.0	
Bethlehem Cornwall pellets	Pa.	1958	1500	63.0	
Low Phos Iron Co. (Hanna)	Ont.	1959	550	62.0	
Groveland (Hanna)	Mich.	1959	700	60.0	
Total			18,200	63.0	8.2
UNDER CONSTRUCTION OR DEFINITELY PLANNED BY 1965					
Lac Jeannine (U. S. Steel)	Que.	1961	8000	66.0	
Republic Increase	Mich.	1961	600	63.5	
Meramac (Bethlehem)	Mo.	1962	2000	64.0	
Atlantic City (U. S. Steel)	Wyo.	1962	1000	65.0	
Humboldt Increase	Mich.	1962	300	63.5	
Carol Lake (Hanna)	Que.	1963	6000	66.0	
Wabush (Pickands Mather)	Que.	1963	6000	66.0	
International Nickel Increase	Ont.	1964	850	68.0	
Reserve Mining Increase	Minn.	1962	4000	62.5	
Total			28,750	65.3	5.0
TRADE PRESS PREDICTIONS BY 1970 (Finance and Market Permitting; Sufficient Reserves Already Proved; Concentrating Tests Completed)					
Taconite and Jasper Concentrate in Addition to Above*	U. S. Upper Great Lakes	Prior to 1970	13,300	62.6	
Anaconda	Ont.	1965	2000	65.0	
Normanville (J. & L., Cleveland-Cliffs)	Que.	1965	2000	65.0	
Noranda	Que.	1965	100	68.0	
Minerals Engineering	Mont.	1965	200	65.0	
Agenda (Detroit Steel)	Wis.	1965	500	65.0	
Labrador M. & E. (Timmins)	Que.	1965	4000	68.0	
Rio Tinto	Ont.	1966	1000	66.0	
Can-Fer	Ont.	1966	1000	65.0	
Jalore (J. & L.)	Ont.	1968	1000	65.0	
Albanel (Cleveland-Cliffs)	Que.	1968	3000	66.0	
Southern Pacific Railway	Nev.	1968	1000	66.0	
St. Joseph (Steep Rock)	Ont.	1970	3000	65.0	
Ungava Iron (Cyrus Eaton)	Labr.	1970	5000	65.0	
Great Whale (Little Long Lac)	Labr.	1970	2000	66.8	
Woodward Iron Co.	N. J.	1970	1000	68.0	
Total			40,100	64.5	6.0

* From U. S. Tariff Commission Report, March, 1959; specific locations not stated.

RECAPITULATION

Now Installed	18,200	63.0	8.2
Under Construction or Definitely Planned	28,750	67.0	4.0
Possible Between 1965-1970	40,100	64.5	6.0
Total	87,050	64.5	5.8

NOTE: The above does not include old-established and conventional sources of high grade concentrate such as the Adirondacks, Pennsylvania, New Jersey, and Tennessee Copper, now totalling about 3 million annual tons at 64 pct Fe.

Table III. Expected Analysis High Grade Concentrates and Ores (Dry Basis), Pct

Property	Fe	SiO_2	Al_2O_3	Rice Ratio*	CaO	MgO	Mn	S	P
Concentrate (in Production)									
Reserve Mining	62.48	9.0	0.54	6.55	0.50	0.65	0.22	?	?
Cleve. Cliffs	63.66	8.98					0.05	0.005	0.035
Erie	62.8	7.0	0.5	8.3					
Marmarton	64.85	4.0	0.5	13.0					
Hilton	67.08	1.84	0.36	30.4	0.44	0.53	0.08		0.005
Int. Nickel	68.0	1.5	0.65	32.0	0.25	0.30	0.05	0.01	0.003
Bethlehem Grace	63.0	4.9	0.5	8.6			0.05	0.047	
Low Phos Iron	60.06	7.42	0.45	7.7	1.50	1.48	0.71	0.02	0.02
Tenn. Copper	68.0	1.5	0.3	37.6					
Concentrate (by 1965)									
Quebec Cartier	66.19	4.67	0.32	13.20	0.02	0.03	0.02	0.005	0.03
Carol Lake	66.0	4.75	0.30	13.10					
Wabush	66.50	4.00	0.30	15.50					
Meramac	64.0								
Atlantic City	65.0								
Concentrate (Possible by 1970)									
All	63-67								
Overseas Direct Shipping Ores (Present or Future)									
Cerro Bolivar	63.75	0.74	1.06	35.4	0.29	0.26	0.02	0.03	0.068
Bethlehem, Venezuela	68.0	0.30	1.90	30.8			0.05	0.03	0.03
Marcona, Peru	60.5	7.0	1.5	7.1	1.2	1.0		0.17	0.055
Liberia	63.0	3.0	0.7	17.0				0.04	0.07
Brazil	68.5	0.43	0.51	72.8			0.07		0.036

* Rice Ratio is: $\frac{Fe}{SiO_2 + Al_2O_3}$

screen analyses for the concentrate from the three new Wabush Lake concentrators.

Expected Screen Analyses of Concentrate

	Lac Jeannine (U.S. Steel)		Carol Lake (IOCO)		Wabush (Pickands Mather)	
Tyler Mesh	This Mesh, Pct	Cumulative, Pct	This Mesh, Pct	Cumulative, Pct	This Mesh, Pct	Cumulative, Pct
20	19.8	19.8	0.3	0.3	0.98	0.98
28	—	—	2.3	2.6	4.15	5.13
35	39.9	59.7	6.4	9.0	8.98	14.11
48	—	—	10.9	19.9	17.74	31.85
65	26.8	86.5	21.2	41.1	20.07	51.92
100	6.7	93.2	20.8	61.9	21.23	73.15
150			17.2	79.1	13.55	86.70
200			11.9	91.0	8.67	95.37
−200			9.0	100.0	4.63	100.00

Such material is not only much coarser than anything in previous pelletizing experience but, at the same time, is too fine for sintering by conventional means, taken by itself, without prohibitive sacrifice in production per square foot of grate area per day, due to reduced bed permeability as a function of grain size. Some may be on the sinter border-line.

The nub of the problem lies on the *green strength* of the pre-fired pellets, which, of course, includes persuading them to roll into pellets in the first place.

The individual grain can attach itself to the forming glomerule only through that portion of its surface that comes into contact with it. Surface is a function of the square of the particle diameter. The particle is to the glomerule what an alpine climber is to a cliff: gravity and nothing but gravity is trying to pull him down against the strength of his own muscles. His weight is a cubical function but his strength is limited by the square diameter of his biceps. That is essentially the reason why (a) houseflies can walk on the ceiling but elephants cannot, and (b) −200-mesh concentrate pelletizes easily but 28-mesh does not.

The layman immediately sees an easy way out: to pelletize 28-mesh concentrate, just grind it to 200-mesh first. He would confer validity upon our horse-sheep-cat-mouse metaphor by proposing the sausage route.

The cubes-vs-squares discipline quickly dims that hope because Rittinger's Law says that the energy required for grinding any material is proportional to the new surface produced. Therefore the energy requirement is over ten times as much to reduce a ton of 20-mesh material to 200-mesh as had been required to reduce that same ton from 8 in. to 20-mesh. Considered as perfect cubes, this is the way it works out:

	Surface Area, sq. in.
An 8-in. cube	384
The same cube reduced to 20-mesh	93,400
The same cube reduced to 200-mesh	1,059,300

What sense would it make to take pure Labrador concentrate and spend vast amounts of energy grinding it to flour in order to pelletize it and so make it a little coarser than it was to begin with? On the above surface area relationship, this necessitates three times as much energy as was required to grind the total crude ore to the 20-mesh concentrating size, assuming that you grind three tons of crude ore, throw away two tons of tailing without regrinding, and regrind the remaining ton of concentrate to 200 mesh.

To grind to 200-mesh at any one of the Quebec-Labrador concentrating plants now under construction would require about 25,000 additional installed horsepower at each place, according to D. N. Vedensky, who verified his arithmetic by actual grinding tests. The capital cost of the required power plant and grinding plant would come to about $20 million. The operating cost, including interest on the investment and all other indirect costs, would be about 75¢ per ton.

There is no gainsaying that this procedure would accomplish the objective; in fact, there is one commercial plant elsewhere that is doing it now. Whether there might be better or cheaper ways to do it is still to be researched.

The surface-mass discipline relates to the earlier-mentioned analogy of putting rocks in the dough, as the case might have been in the pioneer days of sintering. As for "turning the oven off at the same time," that relates to much of the Quebec-Labrador concentrate being hematite instead of magnetite. The operating records at both the Erie and Reserve taconite plants in Minnesota show that about 28 pct of the total heat requirement for firing pellets comes from the exothermic reaction of the magnetite itself in transforming to hematite. The cost accountants there gratefully accept this as free *manna from Heaven*, but who is going to persuade the Labrador cost accountants to be equally broad-minded when the difference must be made up in purchased fuel? Nor can the added fuel be molecularly dispersed in the crystal lattice as the ferrous iron in magnetite.

Blast furnace outlook

For those concerned with the blast furnace aspect of the new ore supply, O. R. Rice is required reading. He has no doubt—and leaves his readers none—that the blast furnace is on its way to all-time highs in both capacity and efficiency. He ventured to predict new US furnaces of 4000-tpd capacity, as soon as adequately prepared high-grade raw materials could be made available, in keeping with recent advances in blast furnace technology. So swiftly has the raw materials outlook changed, that less than four months later, plans for a blast furnace in the Pittsburgh district were announced with such an orbit as its ultimate goal.

In our historical vein, the more telling points of the Rice analysis are that (a) blast furnace practice had remained an art for decades until an ore crisis intervened after World War II, (b) comparing 1959 with 1950, the percentage of beneficiates in the burden nearly trebled, along with marked increase in use of foreign high-grade ore, both duly reflected in a 15 pct decrease in slag volume, and (c) either as a coincidence or a result—or both—there was a great upsurge in enterprise to improve practice.

The net outcome over the decade, according to Rice, was an increase of 26 pct in hot-metal production (from 1233 to 1550 net tons per furnace-day) and a decrease of 16 pct in coke rate (from 1747 to 1470 lb per ton of iron).

These spectacular improvements were independent of the strong trend during the same period to furnaces of greater hearth diameter. Arbitrarily

taking 25-ft diam and over as the definition of a *large* furnace, he notes that 56 out of the 239 US furnaces existing in 1950, or 23 pct, were large by that measure. Their number, he says, had increased to 87 by 1959, or 35 pct of the new total.

It is instructive to look back at what H. S. Harrison had to say two years before Rice lit up the dark areas of the stage:

> "When an ore of 62 pct Fe replaces ore with 52 pct the production of a blast furnace will be increased by 20 pct in iron analysis alone. If a company has five furnaces, in effect they have built a sixth if they use high-grade ore. Their labor costs will be correspondingly reduced because the same crew would be used to get the additional tonnage. It is as simple as that."

In this particular context, the Rice analysis reveals that Harrison wrought better than he knew, especially when Harrison went on to say that blast furnace capital costs have trebled and wages have quintupled, periods of comparison not stated.

Not to allow for blast furnaces getting bigger was his understandable omission. He expressed sorrow that the capital cost of a blast furnace has gone up, but if the productive capacity might increase in proportion, the capital cost per ton of capacity is the same. As for labor costs, even they are supposed to be geared to productive capacity.

In other words, Harrison was really right in saying that higher grade ore would permit us to stay within economic limits with the equipment we had at the time he wrote. He might have added that, with the higher grade ore, we could afford—at long last—to replace the old with something newer and bigger and better. Now the blast furnace operator can actually cash in on the ingenuity he had not even had to exercise until the iron miners began to get into trouble.

If at this same time the railroads and the marine carriers had announced a 20 pct blanket cut in transport rates, every newspaper in the country would have carried banner headlines on the front page. The reality is that such a cut has in effect already been made on high-grade ore (though without the headlines), as will next be seen.

As Harrison might have said, an increase of 20 pct in Fe grade is 20 pct reduction in the cost of hauling iron units. Freight rates are fixed by the gross ton-mile. If the ton-in-the gondola or the ton-in-the-hold contains 62 pct Fe instead of 52 pct Fe the cost of hauling a unit of iron has decreased by 20 pct.

After five decades of denying really robust health to blast furnaces due to silica, sulfur and phosphorus tapeworms, we now face the irony of too rich a diet. It has come to pass that the blast furnace is threatened with the equivalent of gout. On the ultra high-grade burden, the problem is slag volume to scavenge the coke sulfur. For any ore having an iron to silica plus alumina ratio greater than about 14 to 1, a make-up slag would have to be produced by arbitrarily charging a ballast material in the form of silica rock or the like, plus a corresponding amount of additional flux stone.

In Table III, this Rice ratio is calculated for the individual ores and concentrate for which analytical data are available. It will be seen that: (a) there is no new problem on taconite or Ontario concentrate, whose ratios are in the range of 6:1 to 8:1. (b) Labrador concentrate is right at the critical limit at 13:1 or 14:1. This is the material of which an annual production of 20 million tons is already definitely planned, with more to follow. (c) In the new concentrate tonnage outlook, there is fairly substantial representation in the 30:1 range which would require *ballast*, either as such or in the form of higher-silica ore from other sources. (d) Practically all of the impending tonnage of high-grade overseas direct shipping ore is in the 20:1 bracket. Brazilian, Chilean, and Liberian ore would require dilution, just as Venezuelan does now. Wabush concentrate is too close to borderline to serve that purpose.

Thus, broadly speaking, the use of ultra-high grade ore or concentrate poses a queer handicap, almost as preposterous as the one referred to above in connection with pelletizing. There we saw that—unless research finds a better way—conventional pelletizing would require impending Labrador concentrate to be ground finer in order to agglomerate it into something coarser. In this impending grade situation blast furnaces face the need to add silica to the burden artificially, with extra lime to flux the extra silica and thereby cancelling out some coke-saving which the high-grade aimed for. This is a wry reward for the beneficiation engineer who has spent a lifetime trying to take silica out of ore and put it on the dump where it belongs and which in the case of direct shipping ore Nature required a billion years to accomplish. A literal parallel would be to ask the oxygen people to put some nitrogen back into their beneficiated air.

As Rice makes clear, the slag volume is needed only as a vehicle to carry coke sulfur away from the iron. He cheerfully agrees that such a course would be followed only if a more sensible one cannot be found—which is exactly what the pelletizing people say about their problem, too.

The past record shows that for 30 years the percentage of sulfur showing up in metallurgical coke has remained essentially constant at about 60 pct of the gross sulfur in oven charge coal, the remainder being passed out with oven gas. (The sulfur content of blast furnace coke continues to range from 0.6 to 0.9 pct, depending on the coals in use). It is true that coal preparation methods have improved and that a much higher proportion of charge coal is now washed, but beyond the larry car, sulfur still follows the traditional distribution. Cumulative improvements in washing practice have reduced ash about in proportion to reduction in pyritic sulfur and hence have not increased the sulfur-carrying power of coke ash in the blast furnace. Both have about reached their limit. Indeed, in these respects we have been lucky to more or less hold our own in the face of inexorable increasing necessity to draw upon raw coals of higher and higher sulfur content after half of a century of skimming the cream of the coal mines.

Conclusion

When told in perspective, the story is one to make the old-timer proud that he was around to see most of it happen, beginning in 1892. By equal time measure, some young-timer considering the strides being made in gerontology—should be able in April, 2030, to report even greater accomplishments by his associates and immediate predecessors. But let us not extrapolate. By that time we may be getting artesian iron from Mohole.

2.8 × 8.5 m converters at Hitachi Smelter.

COPPER SMELTING IN THE CONVERTER

Pilot-plant and commercial-scale tests on the smelting of copper concentrates in the converter are described. It was concluded that oxygen enrichment of the converter air would be the best means of improving the heat balance of the operation.

by Tamon Tsurumoto

The post war development of the Japanese copper industry has been characterized by progress in flotation methods and improvements in the production of sulfuric acid from smelter gases.

In this connection, the author has studied methods of smelting copper concentrates directly in a converter[1], and the more efficient utilization of converter gas for the production of sulfuric acid[2]. It was concluded that oxygen enrichment of the converter air would be the best means of improving the heat balance of the converting operation for the purpose of smelting concentrates in the converter.

The first converter smelting test with oxygen enriched air was carried out in 1951 at the Saganoseki Smelter, using a commercial-size converter supplied with bottled oxygen. Following this first experiment, another 14 tests were carried out in the course of one year during which approximately 5000 bottles of oxygen were consumed.

After having proven the feasibility of smelting copper concentrates in a converter with oxygen-enriched air, it was necessary to investigate the process in detail in order to determine the optimum operational conditions for the utilization of the method on a commercial scale. For this purpose, it was necessary to conduct tests of longer duration, for which larger quantities of oxygen would be required. Consequently, an oxygen unit with a capacity of 120 liters of liquid oxygen per hr was installed in 1952 with financial assistance from the Government of Japan. A total of 109 tests were carried out on a semi-commercial scale during the following two years.

The test program included the following seven stages:

1) Treatment of specially-selected typical concentrates;
2) Treatment of concentrates from different sources and comparison of their behavior;
3) Treatment of mixtures of concentrates blended to simulate typical charges at the Saganoseki Smelter;
4) Investigation of the effects of variations in the operating conditions;
5) Treatment of simulated charges corresponding to expected future concentrate deliveries;
6) Repetition of previous test series following a revision of the expected future concentrate deliveries; and
7) Treatment of Hitachi copper concentrates, for the purpose of studying the possible commercial application of the process at the Hitachi Smelter.

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The tests were carried out at the Saganoseki Smelter in a Peirce-Smith converter, details of which follow:

Shell dimensions:	2.6 m diam x 5 m length
Tuyeres:	total 24; 20 normally used; diam: 32-38 mm
Lining:	chrome-magnesite brick
Blower:	Rateau-type turbo blower; vol of blast: 185 cu m/min; pressure of blast: 700 mm Hg.

The concentrates were supplied from a 10-ton bin feeding a belt conveyor which delivered the concentrates into the converter through a chute.

Liquid oxygen was stored in a 9-cu-m tank which could be filled with liquid oxygen in approximately 72 hr. This permitted tests to be carried out every three or four days, using 8000 to 10,000 liters of liquid oxygen, or 7000 to 8000 cu m of oxygen gas at a time.

The liquid oxygen was evaporated by steam heating, giving an oxygen gas of sufficient pressure to be blown directly into the converter air supply pipe. The concentration of oxygen in the enriched air was controlled by regulating the liquid oxygen pump. Thus, the oxygen flow could be controlled within the range of 0 to 25 liters per min, corresponding to a maximum volume of 20 cu m per min. The flow could be regulated at intervals of 1 cu m per min, when rapid changes were required.

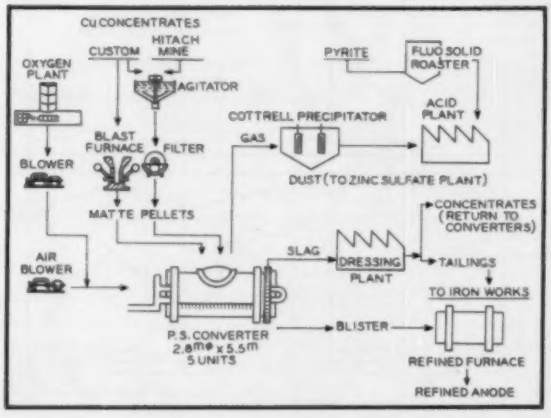
The pressure of the oxygen before reaching the air pipe was 4 to 5 kg per sq cm. The volume of oxygen enriched air was 90 to 100 cu m per min. At an air flow of 70 cu m per min and an oxygen flow of 20 cu m per min, the oxygen concentration in the enriched blast is 38.5 pct.

Starting matte

It is necessary to have a pool of matte in the converter before charging concentrates and flux. At the Hitachi Smelter this *starting matte* is obtained from a blast furnace which was retained for this purpose when the smelter was changed from blast-furnace smelter to converter smelting. The blast furnace is practical because it is used for smelting various reverts as well as some lump ore, but the starting matte could equally well be provided from a reverberatory furnace.

The Hitachi starting matte contains from 40 to 50 pct Cu. It would be better to use a lower grade matte, but inclusion of some oxidized ores and reverts in the blast-furnace charge results in the production of a matte of comparatively high grade.

The converter smelting cycle is started with approximately 10 tons of molten starting matte. There are no further additions of molten matte to the converter during the remainder of the cycle ending with blister copper.



Flow sheet of the Hitachi Smelter.

Charging method

A simple and practical method to charge the converter is through a retractable chute. The rate of charging can be regulated by using a belt feeder with variable speed motor for delivering the raw materials to the charging chute.

Silica is required for the formation of slag in the converter. In the early tests, silica flux was charged separately after having first melted the concentrates. These tests showed that the addition of silica flux was not necessary when the concentrates and ores contained sufficient silica to form slag.

It was also apparent that better results could be obtained by feeding a small amount of concentrates, together with flux, at short intervals, rather than feeding large quantities of flux separately at widely-spaced intervals. With the latter practice, smelting operations were impaired by fluctuating converter conditions and, in some cases, by thick smoke from the converter.

Dust recovered from the converter hood, dust chamber, and flue is returned for retreatment, while the Cottrell dust is sent to a zinc and lead recovery plant.

Matte enrichment process

The grade of matte gradually decreases during the charging of copper concentrates into the converter, but the grade again increases during the subsequent charging of silica flux. This phenomenon can be explained in the following way: As copper concentrates are charged, the melting rate exceeds the oxidation rate of FeS, and the matte grade decreases. During the flux charging period, on the other hand, the concentrates are already melted but the oxidation of FeS continues, thus causing an upgrading of the matte. However, excessive charging of silica flux results in the formation of an increased quantity of slag, which requires more heat to remain fluid. This heat can be supplied by increased oxidation of FeS with resulting enrichment of the matte. In practice, it is recommended that the converting operation be controlled so as to keep the matte grade as low as possible.

As smelting proceeds, the rate of matte enrichment decreases for each slag forming period until the matte grade finally reaches 70 pct Cu. The white metal stage has now been reached and further smelting of concentrates is no longer possible. The white metal charge is now blown to blister copper.

Charging rate

Control of the concentrate charging rate is essential for achieving satisfactory and uniform smelting conditions in the converter. If the feeding rate is not properly controlled, the heat balance is upset, and the converter may be damaged. Therefore, a

Table I. Examples of Slag Composition

Slag Constituent	Test No. 5-3				Test No. 5-7			
	Cu	Fe	SiO_2	Fe^{+++}	Cu	Fe	SiO_2	Fe^{+++}
1st Matte Forming Period	2.44	50.44	17.73	10.60	1.42	48.80	19.50	6.26
2nd Matte Forming Period	4.15	45.91	19.45	7.91	1.05	46.81	21.60	5.03
3rd Matte Forming Period	2.18	45.43	22.13	8.96	6.10	46.96	17.03	14.62
4th Matte Forming Period	1.96	49.24	19.36	9.00	4.66	44.24	19.40	11.44
5th Matte Forming Period	3.71	47.80	19.22	9.50	3.70	46.57	19.12	15.11

Table II. Comparison of Blister Copper Grades

Sample	Cu, Pct	
	O_2 Enriched Blowing	Air Blowing
1	98.62	98.67
2	98.81	98.59
3	98.88	98.57
4	98.95	98.66
5	98.92	98.39
6	98.86	98.50
7	98.85	98.57
8	98.64	98.44
Avg	98.82	98.35

Table III. Performance of Sulfuric Acid Plant on Oxygen Converter Gas

Test No.	Vol Gas Treated, N cu m/min	SO_2 at Acid Plant Converter Inlet, Pct	Conversion, Pct
1	218	9.43	92.54
2	210	8.48	93.11
3	218	9.84	91.61
4	218	7.90	92.88
5	216	10.00	91.45
6	214	9.05	92.12

main objective throughout the test program was to learn how to control the feeding rate. It was concluded that the concentrate feeding rate should be controlled in such a way as to maintain the converter temperature at 1000° to 1050°C, the minimum temperature at which molten matte and unmolten slag can co-exist, and where normal circulation of the melt is still possible. The temperature inside the converter is interpreted by flame color and blast volume, since it is not feasible to measure it by simple means. A concentrate charging rate of 200 to 300 kg per min was found suitable for the Saganoseki converter.

Magnetite formation

It was expected that much magnetite would be formed when charging silica flux after smelting concentrates, but actually no difference from conventional converter practice could be observed. This was probably due to the following reasons: 1) the concentrates contained a significant amount of SiO_2, and 2) the presence of a large quantity of FeS in the converter during charging prevented the formation of magnetite.

The content of magnetite in slag was checked by chemical determination of Fe^{+++}. This content is approximately 10 to 12 pct in conventional copper smelting. In oxygen smelting, the magnetite content tends to increase as the smelting proceeds, leaving less FeS in the melt. This trend is particularly noticeable when starting matte is blended with recycled material from more advanced stages of the smelting cycle. The variation of slag analysis during the smelting cycle is shown in Table I.

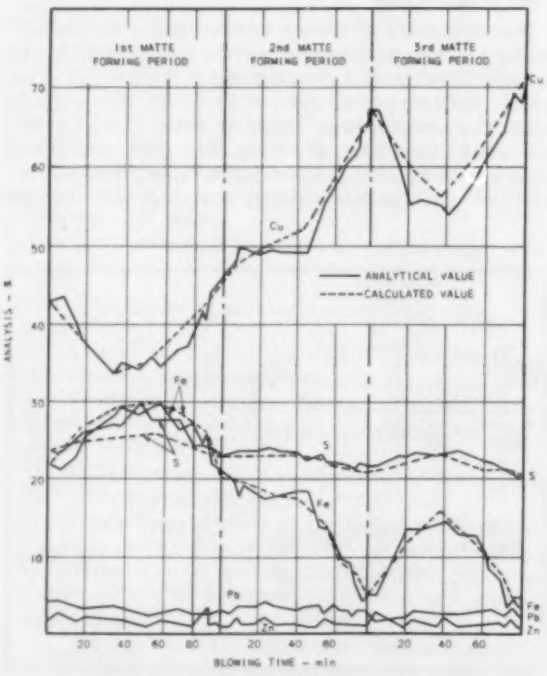
The quantity of flux charged is one of the essential factors influencing magnetite formation. Since the Fe^{+++} content increases with lower SiO_2 content, it is advisable to keep the Fe^{+++} content low in the slag by adding sufficient amounts of silica flux. However, the reduced iron content naturally lowers the value of the slag as a raw material for steelmaking, and the heat generation is adversely affected by the increased slag formation. In practice it has been found that the desirable content of SiO_2 is between 18 and 20 pct.

Copper quality

Table II shows comparative grades of blister copper produced from identical charges by blowing the converter with oxygen enriched air and with air alone. From these figures it would appear that a higher grade of blister copper is obtained by oxygen smelting. The higher copper analysis is due to a reduction of the lead and nickel contents. While the removal of lead is desirable, the loss of nickel deprives the electrolytic refinery of a valuable byproduct. It is easy to overblow the copper with oxygen enriched air; therefore it is recommended that air alone be used in the latter part of the finishing blow.

The slag

The heat generated in the converter must be sufficient to maintain the slag at a temperature at which it is fluid. Even slags containing more than 10 pct of



Change in matte composition during converter cycle.

such components as Al_2O_3, CaO, BaO, etc. can be handled, provided sufficient heat is generated in the converter. However, when the slag is to be used for steelmaking, these constituents should be reduced to the permissible limit by removing them from the copper concentrates.

The utilization of converter slag as a steelmaking raw material requires the removal of copper from the slag. With this in view, tests were performed by decopperizing in an electric furnace and by separation by flotation.

In the former tests, slag was charged from the holding vessel into the electric furnace in a molten state. Coke and other reducing agents were added, and the magnetite in the slag was reduced. In this manner, tests were conducted to find means of separating copper by allowing it to settle in the matte. However, it was not possible to lower the copper content in the slag below 0.30 pct, and in view of the high power costs and treatment charges, the idea of applying this process in practice was abandoned.

On the other hand, it was determined that the flotation process was more economical and indicated the feasibility of reducing the copper content in the tailings to a figure below 0.3 pct; therefore, it was decided to adopt this process.

The capacity of the slag dressing plant erected at Hitachi Smelter is 180 tpd. At this plant, the converter slag is separated into concentrates and tailings, the latter containing under 0.3 pct Cu and over 50 pct Fe. The concentrates from the slag treatment plant are mixed with the other copper concentrates and returned to the smelting converters, while the tailings after dewatering are sold to steel mills.

Acid recovery

Blowing with air, enriched to over 30 pct O_2, should give a converter gas containing more than 20 pct SO_2; however, the gas strength is observed to change during and after the feeding of concentrates. After the feeding of concentrates, the SO_2 content of the gas decreases because less sulfur is available for oxidation in the converter. Part of the oxygen then appears to pass through the converter without reacting.

From the viewpoint of conversion to sulfuric acid, there is a deficiency of oxygen in the highly concentrated gas. It must, therefore, be diluted with air. This air is introduced at the entry to the drying tower so as to limit the volume through the gas purification plant to the converter gas itself. Standard conversion rate at the Saganoseki plant is approximately 97 pct with a feed gas containing 6.5 pct SO_2. Table III shows some results obtained during the third test period. It can be seen that the conversion rates are fairly low, but the conversion can be improved by reducing the SO_2 content to 6 to 7 pct at the inlet of the acid plant converter.

The behavior of free sulfur produced by thermal dissociation of sulfides has been seriously studied from the beginning of the tests, but it was not possible to obtain quantitative data by actual measurements. However, it was possible to obtain qualitative information by gas analysis and blast calculation.

The blast efficiency of the converter would become unreasonably low, if it were assumed that the free sulfur is not oxidized. In tests where large quantities of pyrite were charged into the converter, the calculated blast efficiency would be only 50 pct on this basis. Gas analysis shows, however, that the oxygen content in the converter is less than 1 pct, indicating a much higher blast efficiency.

At the other extreme, if it is assumed that the free sulfur is totally oxidized in the furnace, there would be a theoretical deficiency of oxygen, resulting in a blast efficiency of over 100 pct. It was concluded, therefore, that after oxidation had taken place to a certain extent, some free sulfur escaped from the converter. It can be assumed that most of the free sulfur which escapes is oxidized at the mouth of the converter. This assumed behavior of the free sulfur is supported by the following facts. The oxygen content of the gas in the converter flue is 1 pct when feeding charge, but it gradually increases to about 5

Table IV. Heat Balance—Converting with Atmospheric Air

Heat Generated		Heat Consumed	
Exothermic Reactions	Cal	Endothermic Reactions	Cal
$Fe \rightarrow FeO$	168,352	$CuFeS_2 \rightarrow Cu_2S + FeS + FeS_2$	4,326
$Fe \rightarrow Fe_3O_4$	162,929	$FeS_2 \rightarrow FeS + \frac{1}{2}S_2$	39,361
$FeO \rightarrow 2FeO \cdot SiO_2$	28,753	$FeS \rightarrow Fe + S$	103,210
$Zn \rightarrow ZnO$	58,103	$ZnS \rightarrow Zn + S$	30,667
$S \rightarrow SO_2$	477,350	Sensible Heat in Products:	
		White Metal (finishing matte)	57,730
		Slag	204,800
		N_2	262,894
		SO_2	73,372
		S_2	14,957
	895,967	H_2O	82,950
Heat Deficiency	167,030	Radiation Loss	188,750
Total	1,063,017	Total	1,063,017

Table V. Heat Balance—Converting with Oxygen Enriched Air Containing 35 pct O_2

Heat Generated		Heat Consumed	
Exothermic Reactions	Cal	Endothermic Reactions	Cal
		As in Table IV	177,564
		Sensible Heat in Products:	
		White metal slag, SO_2, S_2 and HO_2 as before	433,809
		N_2	129,697
		Radiation loss	113,250
			854,320
As in Table IV	895,987		41,667
Total	895,987	Total	895,987

Table VI. Itemized Copper Losses

	Conventional Smelting		Converter Smelting With O_2 Enriched Air	
	Cu content, kg	Cu distribution, pct	Cu content, kg	Cu distribution, pct
In blister copper	200 kg × 97 pct = 194.0	97.0	200 kg × 98.3 pct = 196.4	98.2
Slag loss	1000 kg × 0.3 pct = 3.0	1.5	600 kg × 0.3 pct = 1.8	0.9
Dust loss	0.5	0.25	0.3	0.15
Unaccounted and handling losses	2.5	1.25	1.5	0.75
Total (Copper content of concentrates)	1000 kg × 20 pct = 200.0	100.00	1000 kg × 20 pct = 200.0	100.00

pct after the feeding. The temperature of the melt is apparently lower than in conventional converting.

It therefore appears that the free sulfur is partly oxidized in the converter and partly burned at the top of the converter, but some sulfur also escapes the converter without oxidation. It was not possible to determine accurately the proportion of the sulfur for each of these classifications. Generally speaking, however, it seems that about one-half of the free sulfur is oxidized in the converter, and most of the remainder burns at the top of the converter. Only an insignificant amount of sulfur seems to escape the converter, and this sulfur is oxidized in the flue. Consequently, no trouble is anticipated from free sulfur in the flue or in the sulfuric acid plant.

Heat balance

The main operating conditions, such as blast volume and oxygen enrichment, are based on heat balance calculations. And the test results have provided a reliable basis for the procedure used for calculating heat balances.

The calculation of the heat balance is based on the mineral composition of Hitachi copper concentrate, whose main constituents are chalcopyrite, pyrite, zinc blende, and gangue minerals. Assuming that 50 pct of the free sulfur liberated by thermal decomposition of chalcopyrite and pyrite is oxidzed in the converter, the volume of oxygen required to smelt 1 metric ton of concentrates is 215.7 cu m, which corresponds to 1027 cu m of atmospheric air. Assuming further that the blast efficiency is 85 pct, the air volume is increased to 1208 cu m. At a blowing rate of 160 cu m per min, the time required for smelting 1 metric ton of concentrate would be 7.55 min. The result of the heat calculation is shown in Table IV. In this heat balance it has been assumed that the temperature of matte and slag is 1250°C, the gas temperature 1000°C, and the heat loss 25,000 cal per min.

The heat balance shows a deficiency of 167,000 cal. This can be remedied either by additional heat input in the form of extraneous fuel, or by oxygen enrichment of the blast, which reduces the amount of heat removed from the system by the nitrogen in the converter gas and by radiation. When air enriched to 35 pct O_2 is used instead of atmospheric air, the smelting time is shortened to 4.53 min per metric ton of concentrate and the radiation loss is correspondingly reduced. The resulting heat balance is shown in Table V. This calculation shows a heat surplus of 40,000 cal which can be utilized to treat revert materials, etc.

Lining wear

The small capacity of the oxygen plant did not permit continuous operation on a commercial scale. The oxygen smelting operation, therefore, had to be carried out intermittently at intervals of three or four days, during which the converter was used for conventional matte blowing with atmospheric air while the necessary amount of oxygen was being accumulated for the following test. Under these circumstances, the effect of oxygen smelting on the lining wear could not be accurately determined.

During the first half of the test program, the erosion was greater than in conventional matte blowing, due to lack of experience with oxygen smelting. But the results of later tests indicate that there is practically no difference in the degree of wear. However, it has been observed that erosion tends to fluctuate intensely, sometimes over 5 cm, when oxygen is blown, and this may have disturbed the conventional operation which followed.

Lining erosion becomes intense when the oxygen enrichment exceeds 40 pct. Comparative tests with oxygen enrichment to 35, 40, and 45 pct showed increased erosion in the latter two cases due to overheating of the converter. Since no refractory bricks are yet available which will last more than 500 smelting cycles, it is preferable to set the maximum limit for oxygen enrichment at 40 pct.

Copper recovery

Table VI shows the copper recovery and losses for a conventional copper smelting operation and an oxygen converter smelting operation, based on a concentrate grade of 20 pct Cu.

With oxygen converter smelting, the slag volume is reduced to approximately 60 pct of the slag formed in blast furnace or reverbatory smelting. The copper content of the converter slag is, of course, quite high but most of this copper is extracted by the application of ore dressing methods to the slag. The copper content of the tailing is approximately 0.3 pct Cu, about the same as for blast furnace or reverberatory slag. Consequently, the copper loss in slag is reduced from 1.5 to 0.9 pct. The dust loss is reduced because of the smaller volume of gas to be treated in the Cottrell. Finally, the handling losses are also reduced because the process is limited to the converting operation. Oxygen smelting results in reduced losses as compared with conventional smelting, as shown in Table VI. It should be pointed out here that handling and unaccounted losses are usually quite high in Japan, due to the many raw materials used, often in small lots. Also, the recoveries are of course higher, if higher grade concentrates are smelted.

Conclusions

The test results lead to the general conclusion that the converter smelting of copper concentrates with oxygen enriched air is feasible as an industrial operation, and it has the following merits as compared with the blast furnace smelting used by the Nippon Mining Co.

1) Simple flowsheet for treating copper concentrates,
2) Fuel and flux economy,
3) Production of blister copper from copper concentrates in a single step, and
4) Economic recovery of sulfuric acid from high grade SO_2 gas.

Nippon Mining Co. Ltd., therefore, decided to adopt this process at the Hitachi Smelter where a low-pressure air separation plant has been installed for the economic production of the necessary oxygen. In conjunction with the oxygen smelter, a plant has been built for the recovery of copper values and an iron product from the converter slag. The change to oxygen smelting at the Hitachi Smelter has resulted in improved smelting economy, increased copper recovery, and additional recovery of sulfuric acid from converter gas.

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[2] T. Tsurumoto: Concentrated Sulphuric Acid Production From Copper Converter Gas at Saganoseki Smelter, *Trans. Kyushu Mining Society*, Oct. 1951, vol. 19, no. 10.

CONTROL OF BAR SURFACE QUALITY

Making or procuring bars of satisfactory quality is the mutual objective of the steelmaker and user. This paper presents what is currently being done to improve bar quality, and suggests what customers might do to help in attaining higher quality bars.

by V. E. Elliott and J. V. Florchak

Users of semi-finished materials search unceasingly for products of better and better quality. Similarly, their suppliers try just as vigorously to stay abreast of the rising standards of quality their customers require. Both are vitally concerned in the struggle to produce an acceptable product economically.

Bars of satisfactory quality—the making or the procurement of them—is the mutual objective of steelmaker and user. We would like to discuss what is being done at Gary works to facilitate the production of better bars. In support of some of our statements, we have used data from other U. S. Steel Corp.'s plants.

Beginning with the steel producer's responsibility, let us indicate at what stages the surface quality of bars is affected: first, at the melting stage; second, at the primary rolling stage; third, at the inspection-conditioning stage; fourth, at the bar rolling stage; and lastly, at the final inspection stage. Unreasonably, the heaviest responsibility for the quality of bars is the inspector's—because, we suppose, he has the final say, *Go or no go*. The inspector can throw out bad bars, but he can't inspect good quality into them. Quality—good or bad—is established long before the bars are spread on the inspection tables. The very possibility that bars free of detrimental defects can be made at all arises from well-thought-out specifications. We must be sure that order specifications are up-to-date and realistic expressions of the requirement for the intended application and not furnished through habit or custom.

Effect of billet quality

Before discussing a few of the factors which we think should be controlled if satisfactory bars are to be produced, we would like to present data from two programs, conducted at Gary works, that determined the effect of billet surface quality on bar surface quality. Specifically, these two studies dealt with the effectiveness of various conditioning practices as the means of producing a seam-free bar. Magnetic particle inspection was used to detect seams and also to confirm their complete removal.

Table I shows that a seam-free billet can be rolled into an apparently seam-free bar. Two sides of each of two billets were torch scarfed and magnetic particle inspected several times to insure freedom from surface defects; the other sides were not conditioned.

Heating and rolling on the same mill to the same size demonstrated that successfully-conditioned sides of the billets were seam-free on the surface of the bars, but that seams left on the billet persisted on the bar surface. Note that on three of the four surfaces that were not conditioned, the length of the seams remained the same, despite the 6:1 elongation of the bar. The depth of seams was decreased approximately one-third, illustrating that the heating and rolling practice will eliminate seams or reduce their length and depth. On side C of Billet two, we found no seams; however, we found several at the bar stage. These seams were undetectable except by magnetic particle inspection. We are led to believe that even magnetic particle inspection of billets—as critical as any inspection made by the customer on his bars—followed by whatever surface conditioning is required, will not remove the possibility of seams remaining in the billet and subsequently in the bar.

A study that compares the effectiveness of visual inspection and conditioning to magnetic particle inspection and conditioning is presented in Table II. As indicated, magnetic particle inspection, which is more objective and critical than visual inspection, gave us the better surface quality. These billets were magnetic particle inspected, conditioned by chipping, reinspected with magnetic particle, and conditioned again. The purpose of presenting this data is to show to what lengths we must go to obtain a seam-free billet and subsequently a seam-free bar. On the basis of these two studies, we can logically assume that good bars come from good billets rather consistently, but also inferior bars can come from seemingly good billets.

Quality index

Experience has taught us that each grade of steel has a susceptibility to surface faults to a varying, but roughly predictable, degree. Though many factors other than composition are at work in determining whether a good ingot will be a good billet and at last a good bar, data firm enough for evaluation permitted us to assign certain grades an *index of quality*. This index provides some idea of the degree of conditioning we will have to use to keep quality of a particular grade at the desired level.

Table III provides index ratings for several grades of steel. The variation in the surface quality ranges from billets with practically no defects to billets that require prohibitive conditioning and add to our scrap loss. Experience has shown that heats with a good rating—according to index letters ranging alphabetically from A, indicating the

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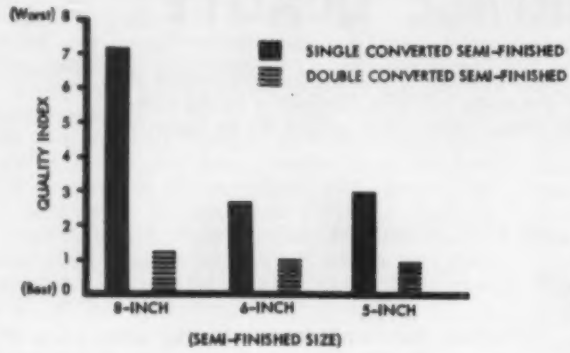
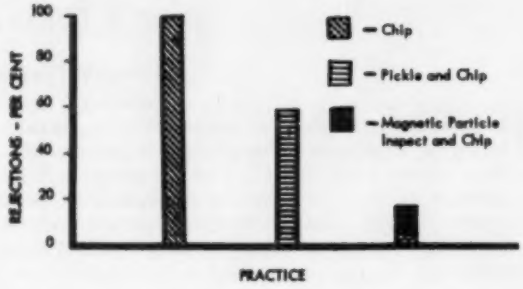


Fig. 1—Left, Effect of conventional practice on bar quality of cold-drawn steel. Fig. 2—Below, Effect of conditioning practice on quality obtained from poor quality billets. (Six 6x6-in. billets rolled to 3-in. rounds).



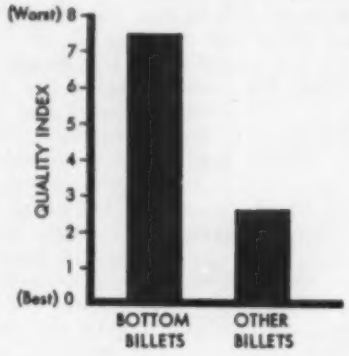
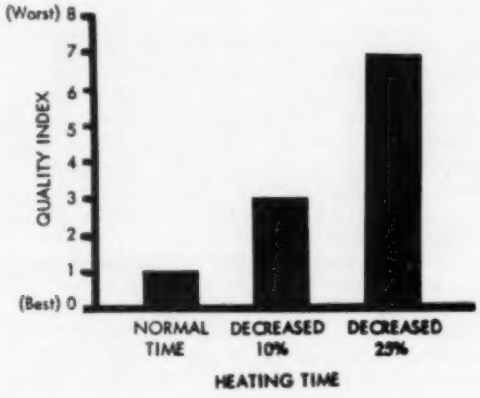


Fig. 3—Left, Effect of bottom billets (6x6-in.) on bar quality. Fig. 4—Below, Effect of heating time on the quality of 1.5-in. rounds rolled from 4-in. billets.



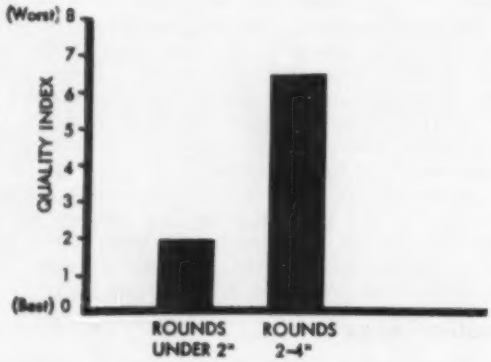


Fig. 5. Left, Effect of rolling reduction on bar quality with 6x6-in. billets.

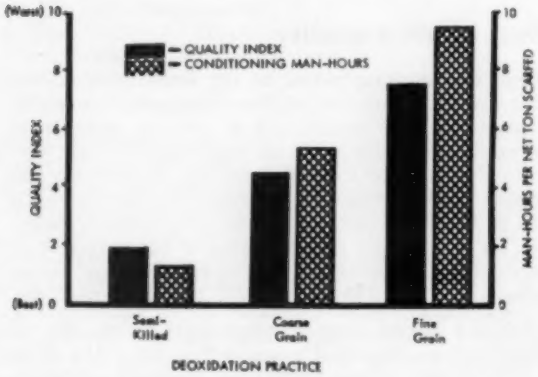


Fig. 6—Above, Effect of deoxidation practice on billet surface quality for C-1020 grade steel. Fig. 7—Left, Quality performance by deoxidation practice.

Table I. Relation of Billet Surface Quality to Bar Surface Quality—4 in. Billets of C-1018 Steel Rolled to 1⅞ in. Rounds

Billet No.	Side[a]	Billet Seams, in. Total Length	Billet Seams, in. Average Depth	Bar Seams, in. Total Length	Bar Seams, in. Average Depth
1	A	260	0.026	257	0.009
	B	513	0.030	1046	0.009
	C	0	0	0	0
	D	0	0	0	0
2	A	209	0.040	204	0.010
	B	413	0.023	535	0.009
	C	0	0	61	0.009
	D	0	0	0	0

[a] A and B—Unconditioned.
C and D—Magnetic particle inspected and conditioned; reinspected and conditioned.

Table II. Effect of Inspection Practice on Surface Quality—4 in. Billets of C-1018 Steel Rolled to 1-15/16 in. Rounds

Inspection Type	Billets No.	Billets Surface Removal, Pct	Bar Product, Pct Rejected Visual Inspection	Bar Product, Pct Rejected Magnetic Particle Inspection
Magnetic Particle	20	17.0	0	0
Visual	21	9.0	1.2	6

Table III. Quality Index—Billet Quality

AISI Grade	Rimmed	Capped	Semi-Killed	Killed
C-1010	B	B	BC	—
C-1015	BC	B	B	C
C-1018	BC	BC	BC	D
C-1020	—	CD	D	E
C-1021	—	—	B	B
C-1024	—	—	—	BC
C-1030	—	—	—	B
C-1038	—	—	A	C
C-1045	—	—	AB	BC
C-1060	—	—	—	AB

[a] Legend:

A	B	C	D	E
Superior	Excellent	Average	Below Average	Poor
Numerical Rating:				
0 to 1.5	1.5 to 3	3 to 5	5 to 7	7 & Over

best surface quality, to E, the poorest—perform well in the bar mills, indicating that the inherent quality of steel persists through rolling more often than not. Experience has also frequently shown that grades requiring the greatest amount of conditioning in billet form are the grades that perform badly in the customer's plant.

The alphabetical rating seemed to be the simplest way to make appreciably distinct the gradations in the billet quality of grades different in carbon, and of grades that differed in being either rimmed or capped, semi-killed or killed. However, a numerical system (0 to 10) offered a way to make finer distinctions in quality between steels involving the factors illustrated. We felt that the rating should be as precise as possible although of necessity remaining relative, even within each grade. Also, in Table III, the alphabetical ratings are assigned their approximate ranges in numerical values.

We have hinted at the direction from which the customer's help should come. He should re-examine his specifications and order steel of the grades with the more favorable quality index rating. But first, we want to make our position clearer: At every phase of the production of bars, we are working toward improved practices that will give us an improved product, regardless of grade.

Conditioning

In many instances, because of the inherent quality of the steel, it is impossible to condition bar steel by usual practices and still meet unusually stringent applications. In these instances, it is necessary to bloom the ingot to an intermediate size, condition out major defects, reheat and reroll the bloom to semi-finished product, and again condition the material prior to bar rolling. Fig. 1 shows the improvement in the quality index associated with the bloom-reroll (double converted) practice on a heat of C-1117 steel. This practice is expensive because the steel is twice processed through the primary mills and conditioning yards and reduces the capacity of heating and rolling facilities. Even with this practice we cannot guarantee a seam-free bar. Fig. 2 evaluates the effect of three increasingly severe conditioning practices on a small number of billets taken from a poor quality heat. Notice that, regardless of the conditioning we used, we could not consistently produce a defect-free bar.

At this point, one might think that the problem of assigning a conditioning practice to a heat of steel is all there is to obtaining billets of a uniform quality. Such is not the case. Not only do we have variation in quality from heat to heat, and from ingot to ingot within a heat because of changes in temperature and chemistry throughout the pour, but also variation within the ingot itself. Fig. 3 illustrates the difference in quality between the product from the bottom of a C-1018 killed, coarse-grain ingot and that obtained from the remainder of the ingot. The product from the bottom of the ingot is consistently inferior; therefore, requires more conditioning. This data shows that the operator must inspect each billet individually to determine how much surface must be removed to obtain a defect-free billet.

Bar rolling

In addition to the surface quality of the billet, one of the factors responsible for the surface quality of the bar is the bar mill heating practice. Fig. 4 indicates that longer heating will remove shallow seams from the semi-finished stock by scaling and will minimize seams in the bar product by improving the plasticity of areas where surface or subsurface imperfections exist.

Rolling rate has an effect on heating time and, in this way, on finishing temperature. Bars rolled at the slower rate (given a longer heating time) had the higher finishing temperatures and the better surface quality. The steel rolled to a smaller size, and given more reduction, also had the better quality. Fig. 5 further illustrates the relationship between the amount of reduction and bar quality. Both bar-sizes were rolled from the same billet-size. The bars of smaller diameter had fewer seams.

Chemistry

Carbon: The effect of carbon content on the surface quality of billets, showed that for the 0.30 to 0.60 pct Mn curve, the quality index reaches a peak at approx 0.22 pct C. For the 0.60 to 0.90 pct Mn curve, the quality index peaks at approx 0.18 pct C. For instance, C-1015 should give a better surface quality than C-1018. On the other hand, C-1021 should be much better than C-1020.

Manganese: The effect of the manganese content on the quality index of steel is as follows:

1) For the 0.18 to 0.23 pct carbon steels, quality improves with an increase in manganese content up to approx 0.75 pct. From that point to approx 0.85 pct Mn, quality decreases and then remains the same;
2) For the 0.22 to 0.28 pct C steels, the best quality is obtained at approximately 0.75 pct Mn;
3) For steels of 0.37 to 0.44 pct C, increasing manganese improves the surface quality; and
4) For steels of 0.13 to 0.18 pct C and 0.08 to 0.13 pct S, surface quality improves with an increase in manganese up to approx 1.15 pct, after which it deteriorates slightly.

Simply increasing the manganese content obviously is not always the way to improve surface quality.

Phosphorus: Within the normal range of phosphorus encountered in open hearth steels, this element has little effect on the quality index of the product.

Sulfur: Much has been written in trade journals about the effect of sulfur on the surface quality of steel. We will make bare mention of the fact that we have fond it necessary to place maximum sulfur limits on the grades of steel which have high index ratings.

Silicon: The quality index is approximately four times worse when the silicon is over 0.20 than when it is in the 0.10 to 0.15 pct range for a 0.29 pct C coarse grain steel. Data collected at Gary works showed that severe cracking is encountered more often when the carbon and silicon content of the steel is approximately equal in the C-1020 chemical specification.

Steel type

We all know the four fundamental deoxidation practices for producing steel: killed, semi-killed, capped, and rimmed. Each practice has advantages and disadvantages for producing a good quality billet and subsequently a good quality bar. However, the benefits to be obtained from each practice is limited by the steelmaker's facilities and product mix. A deoxidation practice followed at one plant to produce a quality bar will not necessarily produce the same quality at another plant.

Fig. 6 makes a comparison of the quality index of semikilled steel to that of coarse and fine steel. These data indicate the decrease in surface quality obtained with increased deoxidation in C-1020 steel. If surface quality is the customer's concern, he should specify non-killed steel unless killed steel is absolutely necessary for other reasons. Also, note that coarse grain steel rolls with a better surface than fine grain steel.

At one plant the rimmed steel produces the best surface quality. However, at another plant capped steel produces the better quality. How do we reconcile the different performances? Why should one plant successfully use a practice that at another plant is not as successful? A logical explanation would be that the plants have different types of facilities and product mix. Each must use the equipment it has for producing a product. For instance, a plant with a highly oxidizing soaking-pit firing pattern would not consistently produce capped steel as good as that of another plant with a lower oxidation level. Also, a plant producing a major portion of its tonnage in rimmed and capped steel would not consistently produce semi-killed steel as good as that of another producing its major tonnage in semi-killed steel. Therefore, each plant, because of its facilities, product mix, and training, knows which practice will produce the best steel, the best billet and finally, the best bar.

In Fig. 7, we have summarized the data accumulated in our studies of the effect of deoxidation practice. This table can be used as a guide in determining which practice will produce the best steel at Gary works. On the basis of the data presented, it behooves us, steelmakers and steel users alike, to take another look at our specifications. Must we continue to order C-1018 (killed) when C-1015 (killed) will do as well—or better, if we want good surface quality? Can we order C-1021 (killed) instead of ity. Can we use capped instead of semi-killed steel? C-1020 (killed)? The higher manganese (at no difference in price) would improve the surface qual- Do we have to order killed steel in the 0.18 to 0.25 pct C range? These are some of the questions we should ask ourselves in determining which chemistry and which practice we should use to obtain a quality product.

We are not advocating any changes in specification which will result in an increase in the price of steel to the customer. We are, however, suggesting another look at what is available, for the purpose of getting the most out of the various grades at our disposal. Many of the specifications were developed years ago and may have become outdated because of changes in equipment, processing, etc.

Summary

We would like to reiterate some points we have already tried, either directly or indirectly, to make:

1) Our steelmaking practices have been developed by the application of a good deal of experience and by the study of a great amount of data collected by heat, by ingot, and even by cut when necessary, Very definitely we have not stopped collecting data, but we realize the shortcomings of the data that we can gather at our plant.

2) To complete the story, the steel producer's special need is data on the performance of his product. At Gary Works we are guided only by the characteristics of our product that we can see and measure. But does it cold-draw well, forge well, machine freely? The customer is the best judge of how our steel works. Needless to say, we hear about it when the steel does not work; but, we also need the story on good performance. Actually, we should have all the information we can get about changes in product design, changes in processing and, we repeat, about any changes (for better or worse) in the way our steel performs.

3) Lack of communication, for example, could catch us in the position of having a customer's steel *in the pipeline* before we learn of certain changes in his processing that might require a corresponding change in ours.

We have done our best to illuminate our side of the supplier-user partnership. We urge the user to shed all the light he can on his side. The benefits from frank and frequent exchanges of information will be bars of better quality.

FURTHER EVALUATION OF BERYLLIDES

This paper—the second of two articles—discusses the behavior of $CbBe_{12}$ and $ZrBe_{13}$ at temperatures below 1000°C, and suggests a course for future action on beryllide programs. The first paper appeared in the May 1961 issue of JOURNAL OF METALS.

by J. R. Lewis

Intermetallic compounds of beryllium, particularly those involving zirconium and certain refractory metals, have recently attracted considerable attention because of their interesting combination of high-temperature strength and oxidation resistance. Their high beryllium content also makes alloys such as $ZrBe_{13}$ and $CbBe_{12}$ attractive for applications requiring low density materials or materials of low absorption cross section to thermal neutrons.

As has been pointed out in an earlier report,[1] the beryllides crystallographically are rather complex structures—$ZrBe_{13}$, for example, being of fcc structure with 112 atoms per unit cell. Slip mechanisms for plastic deformation are difficult to rationalize for these complex systems. Beryllides have a unique history in that their high-temperature properties have been explored in some detail while little or no knowledge has been accumulated on their behavior at intermediate or low temperatures. The high-temperature data for rupture modulus, Young's modulus, and thermal expansion suggests that the beryllides should be more resistant to thermal stress than most ceramic materials. At elevated temperatures (i.e., above 1000°C) this is apparently so. Practical observations have shown, however, that during fabrication or testing of beryllide bodies, fracture often occurs at temperatures below 1000°C and under circumstances suggesting either thermal stress or intrinsic instability as a cause for failure at moderately elevated temperatures.

The purpose of this paper is to discuss the behavior of $CbBe_{12}$ and $ZrBe_{13}$ at temperatures below 1000°C, and thus suggest a course for future action on beryllide programs. Since one limitation of beryllides appears to be their lack of stability at moderately elevated temperatures, emphasis shall be placed upon evidence of abrupt changes in properties which might lead to failure during operation at a particular temperature or over a particular temperature range.

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Plastic slip?

The ability to undergo plastic deformation under conditions of transient thermal or mechanical stresses may spell the difference between survival and fracture of a material in service. The possibility of plastic slip in most metallic alloys can be forecast with no great difficulty because of the simple crystallographic structures encountered in the majority of systems. As one studies the more complex intermetallic compounds, however, the mechanism for plastic slip becomes less obvious. The question becomes one not of predicting the most probable slip interface among several possible planes, but rather of deducing whether any plausible slip mechanism exists at all.

The unit cell of $CbBe_{12}$ is composed of 26 atoms arranged in a tetragonal lattice, with Cb atoms located at the center and at each corner of the cell. The more complex $ZrBe_{13}$ is arranged in a fcc lattice with 112 atoms per unit cell. According to Shoemaker et al.[2] who studied the isomorphous $NaZn_{13}$ system, each Be_I atom would be surrounded by 12 Be_{II} at the vertices of a nearly regular icosahedron, and each Zr by 24 Be_{II} at the vertices of a snub cube.

By applying the concept of a double interface slip zone, as proposed by Kronberg,[3] it has been possible to postulate a slip mechanism for plastic deformation of $CbBe_{12}$. The details of the mechanism will be disclosed in a future paper; but in brief, relative movement of two portions of the lattice with respect to a stationary zone is accomplished by a rotational exchange in position of beryllium atoms across the two zone-interface planes. There are only two slip zone systems operative in the lattice; these are at right angles and with parallel slip directions. As a

consequence of the limited number of slip systems available for plastic deformation, the progress of slip would be expected to be rather effectively blocked at grain boundaries. One might, therefore, expect $CbBe_{12}$ to exhibit the following traits:

1) Measureable ductility in single crystals;
2) In polycrystalline bodies, decreasing ductility with decreasing grain size, and brittle behavior in bodies of fine grain size;
3) Increasing creep rate with increasing grain size; and
4) Low resistance to impact.

The low ductility and poor impact resistance of fine-grained polycrystalline $CbBe_{12}$ has been noted frequently.[1,4,5,6] The effect of grain size upon ductility and creep rate has not been reported or measured. It should be noted at this point that the foregoing predictions make no assumptions as to the effect of impurities. Most of the data reported hereafter and elsewhere in the literature were collected from samples of impure material. The presence of impurities, while quite possibly leading to further embrittlement, cannot bear the whole blame for lack of impact resistance and ductility in $CbBe_{12}$. On the basis of its crystallographic structure, one would not expect $CbBe_{12}$ to exhibit any great amount of ductility in polycrystalline form, even when of the highest purity.

Although the plane and direction of slip predicted for $CbBe_{12}$ have yet to be verified, evidence of slip has been observed around microhardness indentations. Fig. 1 illustrates slip lines near an indentation made with a 50 g load on a diamond indentor at liquid nitrogen temperature (–196°C).

It is not apparent how slip can progress in the more complex $ZrBe_{12}$ structure, and no evidence of slip lines has been noted in microhardness indentations on this material. The slip mechanism for $ZrBe_{12}$ must be extremely limited in direction and plane of operation, and one would, therefore expect only limited plastic slip (if any) to occur.

With proper mechanical design and due care to avoid loading in tension, it is possible to use materials of low ductility as stress-bearing members. It is difficult, however, to avoid transient thermal stresses in power-generating equipment. For this reason, a brittle material can be tolerated only if it is not apt to fail because of transient thermal stresses.

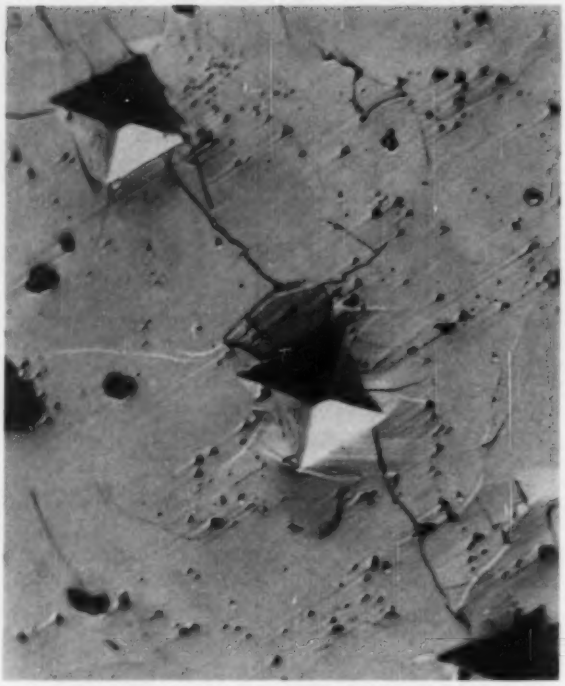


Fig. 1—Impressions made with a Vickers diamond indentor (50-g load) in $CbBe_{12}$ at —196°C. Note faint slip lines at side of center impression and crack running between indentations. Unetched, 1500X, reduced approx 13 pct for reproduction.

The investigation

It has been observed that fractures may occur in beryllide bodies during heating or cooling.[1,4,5,6,7,8] Various factors including surface contamination,

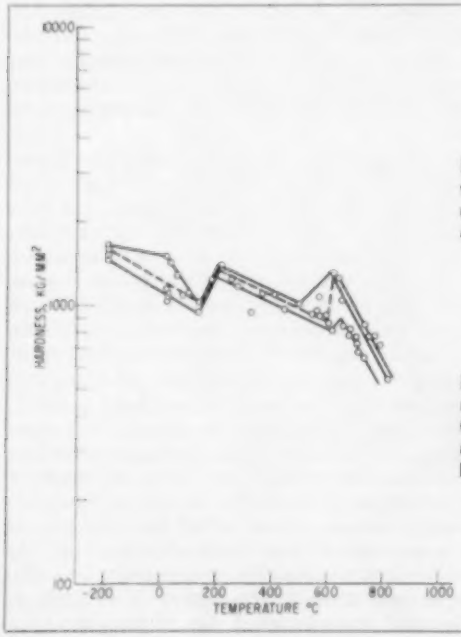


Fig. 2—Left, Microhardness vs. temperature for $ZrBe_{12}$ using Vickers diamond indentor with 50-g load.

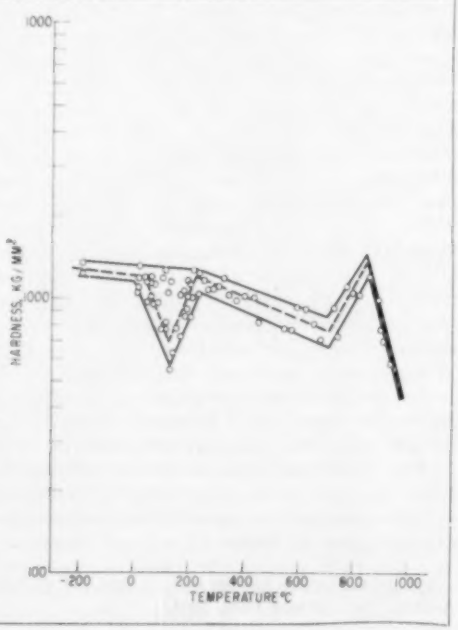


Fig. 3—Right, Microhardness vs. temperature for $CbBe_{12}$ using Vickers diamond indentor with 50-g load.

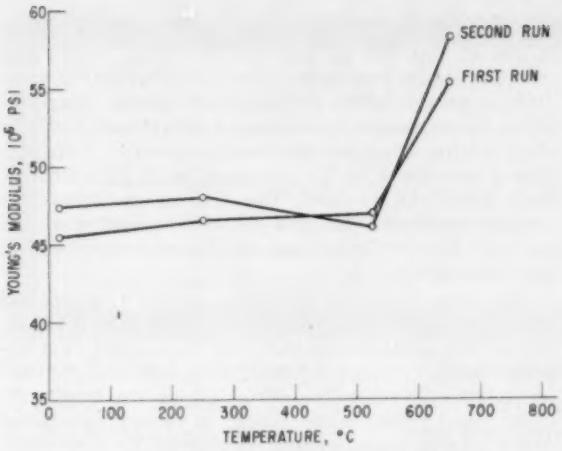


Fig. 4—Elastic modulus vs. temperature for $ZrBe_{13}$.

impurities, fabricating techniques, and atmospheres have been suggested as possible causes for failure, but no serious attempts have been made to explore the behavior of beryllides within the temperature range where such failures occur. With the thought of uncovering some clues to the cause of unstable behavior of beryllides below 1000°C, an investigation was made of the microhardness, elastic modulus, and thermal stability of $CbBe_{12}$ and $ZrBe_{13}$ as a function of temperature. The samples of beryllide used for these experiments were of *as-available* quality, which is to say the impurity level was rather high. Typical BeO content, for example, was 0.8 pct, Si 0.5 pct, and Al 0.08 pct. Because of this, the question of impurities cannot be answered. The results should be interpreted as applying to impure materials and as a warning that any evidence of instability may apply to high-purity beryllides as well.

Microhardness

The microhardness test is an extremely sensitive tool by which one can uncover evidence of phase changes, order-disorder transformations, relative changes in strength, and of course, hardness as a function of temperature. Using equipment described by Westbrook[9] with a 50 g load on a 136° diamond indentor, a hardness survey was made of samples of $CbBe_{13}$ and $ZrBe_{13}$ over the temperature range −196°C to 900°C. The results are presented in Figs. 2 and 3. Two facts are immediately apparent:

1) A low-temperature disturbance occurs in both $CbBe_{13}$ and $ZrBe_{13}$ at or about 150°C, and

2) An abrupt increase in hardness occurs near 800°C for $CbBe_{13}$ and near 600°C for $ZrBe_{13}$.

Such behavior could conceivably be the result of a phase transformation or a precipitation phenomenon. The observed results are also consistent with order-disorder transformations as described by Westbrook.[20] Whatever the cause, it was apparent that the beryllides $CbBe_{13}$ and $ZrBe_{13}$ were behaving in an unpredicted manner, and that additional evidence for the cause of their instability should be sought.

Some data were already available. Chang[11] has reported a discontinuity in the resonance frequency of $CbBe_{13}$ (sic) at 800°C, and inspection of his data reveals a possible inflection at 150°C to 250°C. Paine et al[8] have tabulated data for thermal coefficients of expansion for $CbBe_{12}$ and $ZrBe_{13}$ which also exhibit inflections at the appropriate temperature. It should be noted, however, that the same authors have also published thermal expansion data which do not show any inflections.

An obvious approach to this question was to obtain x-ray diffraction patterns at the temperatures in question for evidence of any phase changes or order-disorder transformations. Unfortunately, high-temperature diffraction equipment was unavailable, and crystallographic data could not be obtained at elevated temperatures.

Elastic modulus

The resistance of a material to thermal stress depends, in part, upon the elastic modulus of the material. If the elastic modulus undergoes an abrupt change over some particular temperature interval, it is apparent that severe localized stresses may be generated. Westbrook[12] has pointed out that Young's modulus frequently increases with ordering when no crystal structure change is involved, and decreases with ordering when there is a change in crystal structure in the direction of reduced symmetry. In view of the indirect evidence for order-disorder transformations uncovered in the microhardness survey, an investigation of the behavior of Young's modulus with temperature was undertaken. Specimens were machined from hot-pressed billets to rectangular prisms approximately 0.185 sq. in. x 1.5 in. long. High-temperature strain gauges (Tatnall type S-710) were cemented to the top and bottom of the specimens, and Young's modulus was computed from stress-strain measurements made at temperatures up to 650°C. The specimens were loaded as four-point constant-moment beams. It was not possible to determine Young's modulus above 650°C because of the gauge limitations. Results for $CbBe_{13}$ and $ZrBe_{13}$ are shown in Figs. 4 and 5. Three observations can be made:

1) A general increase in Young's modulus occurred each time the test run was repeated. This suggests a sluggish transformation or precipitation, a surface reaction/diffusion phenomenon, or a drift in the strain gauge. It is felt that, because of this behavior, the elastic modulus data are significant in a relative sense rather than as absolute numbers.

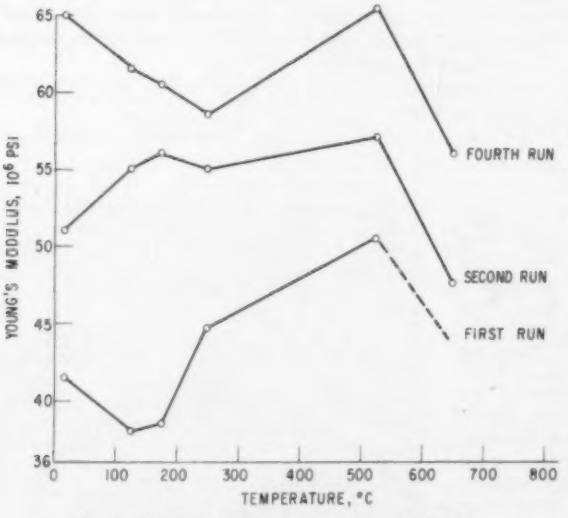


Fig. 5—Elastic modulus vs. temperature for $CbBe_{13}$.

Table I. Thermal Stability Tests on Beryllides

Material	Sample No.	Thermal Cycle T_1, °C	Thermal Cycle T_2, °C	Thermal Cycle No. Cycles	Isothermal Soak	Results
$ZrBe_{13}$	1479	900	700	4	900°C × 16 hr	Intact
$ZrBe_{13}$	1490 A	700	500	4	700°C × 16 hr	Disintegrated
$ZrBe_{13}$	1481	500	300	4	500°C × 16 hr	Intact
$ZrBe_{13}$	1490 B	—	—	—	700°C × 20 hr	Disintegrated
$CbBe_{12}$	A	1100	900	10	1100°C × 83 hr	Intact
$CbBe_{12}$	B	900	700	10	900°C × 83 hr	Oxidized
$CbBe_{12}$	C	700	500	10	700°C × 83 hr	Intact
$CbBe_{12}$	D	—	—	—	900°C × 94 hr	Oxidized

It should be mentioned in support of these data that each point represents the average of at least three determinations at different loads. The scatter at a given temperature and at different loads was less than ± 8 pct within any run.

2) An abrupt increase in elastic modulus was noted for $ZrBe_{13}$ between 525° and 650°C, corresponding to the temperature at which a hardness increase was noted.

3) An abrupt decrease in elastic modulus occurred between 525° and 650°C for $CbBe_{12}$. This is below the temperature range (~700-850°C) within which an increase in hardness was detected. It should be noted, however, that it was not possible to extend measurements above 650°C. It should also be remembered that Chang's data on resonance frequency do suggest an increase in elastic modulus at 800°C.

The experience with elastic modulus measurements on beryllides can be summarized by stating that abrupt changes in Young's modulus occur for both $CbBe_{12}$ and $ZrBe_{13}$ as the temperature is increased, and that these changes amount to about 20 pct difference over a temperature range of 125°C.

Thermal instability

Perhaps the most striking evidence for thermal instability of beryllides can be seen in Figs. 6 and 7. These are photographs of samples of $ZrBe_{13}$ and $CbBe_{12}$ which were exposed to air at temperatures above, below, and within the range over which the abrupt change in hardness had previously been noted. The procedure in each case was to subject the specimens to a number of thermal cycles during the day and to let them soak isothermally overnight. In addition, a specimen was held isothermally at the top of the temperature range where trouble was expected. Details appear in Table I. It is obvious that in the case of $ZrBe_{13}$, almost complete disintegration occurred upon heating at 700°C, with little apparent effect at higher or lower temperatures. Chubb[4] has reported similar results after 1 hr at 700°C and 900°C. Failure of $CbBe_{12}$, while not as remarkable, was near catastrophic at 900°C with little apparent effect at higher or lower temperatures. Room temperature X-ray diffraction analysis after testing revealed the residue powder from the $ZrBe_{13}$ specimens to be composed of $ZrBe_{13}$, Zr_2Be_{17}, BeO, and ZrO_2 (cubic). The $CbBe_{12}$ specimen was heavily oxidized, with a coat of what was apparently BeO, although no analysis was made of the corrosion product.

The gross oxidation of $CbBe_{12}$ at 900°C suggested that the rapid failure of the beryllides at the particular temperatures noted may be related to a reaction with nitrogen or oxygen in the air. An experiment was accordingly run in which samples of $CbBe_{12}$ and $ZrBe_{13}$ were placed in sealed, evacuated fused quartz capsules and subjected to isothermal tests at 900°C and 700°C, respectively. No disintegration or fracture occurred after 100 hr at temperature. Apparently, the catastrophic failure noted previously is a result of heating in air. The explanation may be similar to that advanced for molybdenum disilicide *pest*, which is attributed to a critical thickness and to lack of ductility in the oxide film at a particular temperature range.

The disintegration or catastrophic oxidation of the beryllides, coupled with the other evidence for sensitivity toward particular temperatures, raises serious doubts as to the reliability of these materials as high-temperature structural alloys. Although the cause for their behavior is not firmly established, and may well be found to lie in impurities or composition, there is evidence to suggest an order-disorder transformation or a non-protective oxide film as possible cause for failure.

Summary and conclusions

1) Brittle behavior of MBe_{12} and MBe_{13} beryllides is to be expected in view of their limited mechanism for plastic slip;

2) A reduction in impurity level could reduce, but probably never eliminate, the low ductility of beryllides;

3) There is evidence for an abrupt change in elastic modulus for $ZrBe_{13}$ and $CbBe_{12}$ at or around 600°C;

4) Abrupt changes in hardness occur in both $CbBe_{12}$ and $ZrBe_{13}$ at about 150°C and again in the range 600° to 800°C;

5) Catastrophic failure may occur in $ZrBe_{13}$ if heated at 700°C in air; and

6) Catastrophic oxidation may occur in $CbBe_{12}$ if heated at 900°C in air.

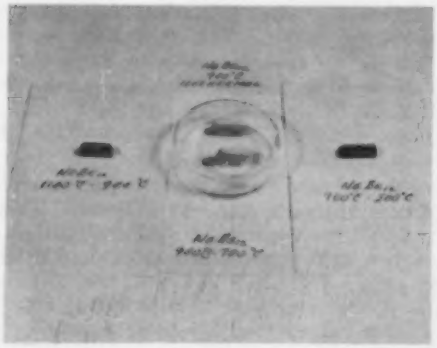
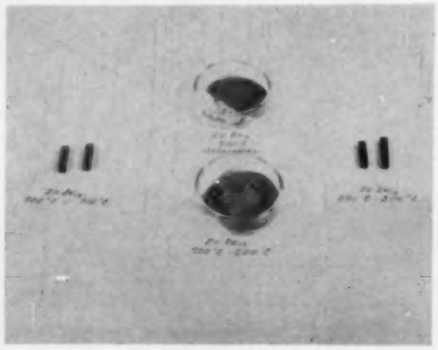


Fig. 6—Left, $ZrBe_{13}$ specimens after testing above (left), below (right), and near (center) the sensitive temperature range. Note that specimens tested at or near 700°C are completely disintegrated. Fig. 7—Right, $CbBe_{12}$ specimens tested above (left), below (right), and near (center) the sensitive temperature range. Note catastrophic oxidation of specimens tested at or near 900°C.



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NEWS OF YOUR PROFESSION

Case Inst. Professor Delivers Lecture To British Metals Group

Alexander R. Troiano, professor of metallurgy and head of the department at Case Institute of Technology, presented the keynote address at the British Iron and Steel Research Institute's *Hydrogen in Steel Conference* which was held in Harrogate, England, October 10-13.

The lecture was based on research conducted in Case's Department of Metallurgy. This research has resulted in new theories of the behavior of metals in terms of their environment, such as hydrogen, oxygen, and nitrogen.

While in Europe, Dr. Troiano will also lecture at Queen's College, Oxford University, le Commissariat á l'Énergie Atomique (French Atomic Energy Establishment), Saclay, l'École de Mines de Paris (School of Mines), and at the new division of the University of Paris at Orsay.

Conference Planned on Beryllium Metallurgy At New York Univ.

A two-day conference on beryllium metallurgy will be held December 4-5 at New York University's Washington Square Center in New York City.

The department of metallurgy and materials sciences of NYU's College of Engineering and the University's Bureau of Conferences and Institutes is presenting the conference, which is being sponsored by the Beryllium Corp. of America and the Brush Beryllium Co.

The program is intended for engineers from industrial, research, and governmental organizations. Conferees will discuss beryllium as a key metal in the field of missile and rocket research, with emphasis on its purification, mechanical metallurgy, welding, brazing, machining, forging, corrosion, and structural applications.

Sixteen papers will be presented covering practical theoretical items in a progressive sequence.

Further information can be obtained from Mel Berk, College of Engineering, New York University, New York 53, N. Y. (Telephone LUdlow 4-0700, Ext. 205).

Magnetism Conference Set For Nov. 13-16 In Phoenix, Ariz.

Speakers from France, UK, and Japan have accepted invitations to present papers at the Seventh Annual International Conference on Magnetism and Magnetic Materials which will be held November 13-16 at the Hotel Westward Ho in Phoenix, Ariz.

The conference is being sponsored jointly by the American Institute of Electrical Engineers and the American Institute of Physics in cooperation with The Metallurgical Society, the Office of Naval Research, and the Institute of Radio Engineers. L. R. Bickford, Jr., of the IBM Research Laboratories in Yorktown Heights, N. Y., is general chairman of the conference.

Among the speakers will be E. F. Bertaut, Centre d'Études Nucléaires de Grenoble, Grenoble, France; E. M. Bradley, International Computers and Tabulators Ltd., Stevenage, England; M. Takahashi, The Research Institute for Iron, Steel, and Other Metals, Tohoku University, Sendai, Japan; and T. Nagamiya, Osaka University, Nakanoshima, Japan.

Professor Takahashi will present a paper on *The Induced Magnetic Antisotropy of Evaporated Films Formed in Magnetic Field.*

A variety of social events, tours, and fashion shows have been arranged for the wives of conference attendees.

Call for Papers

Prospective authors are invited to submit papers to be considered for presentation at an International Conference on Fracture in Crystalline Solids to be held Aug. 20-24, 1962 in the Seattle area under the sponsorship of the Institute of Metals Division.

Papers in the following areas —continuum mechanics, microstructural, atomistic, and environmental aspects—may be submitted to Dr. Hans Brunner, Boeing Scientific Research Laboratories, Box 3981, Seattle 24, Wash.

Transactions Prices Will Increase Jan. 1 By $2.50 Per Year

The Metallurgical Society's Board of Directors has approved an increase in member subscription rates for TRANSACTIONS by $2.50, effective January 1, 1962. The new price will be $7.50 per year for members.

Bound volumes ordered when dues bills are paid will be priced at $7.50. If ordered later, but before the next bound volume becomes available, the charge will be $9.00 per volume. For volumes that go into inventory, the price for members will remain $24.50 per copy.

The price change has been approved by the AIME Board of Directors.

In approving the increase in subscription charges, the Society's Board of Directors has recognized the need to end the continued deficit incurred in publishing TRANSACTIONS OF THE METALLURGICAL SOCIETY. When the charge of $5.00 for member subscription was instituted in 1958, 892 pages were printed (Vol. 212). In 1960, 1148 were printed (Vol. 218). For 1961, 1280 pages are scheduled (Vol. 221). In 1960, actual publishing costs amounted to $19.10 per subscriber. Thus, the member has been able to subscribe at a price well below actual costs, and the modest increase of $2.50 per year seems justified. (The non-member pays $30.00 per year for a subscription to the bi-monthly TRANSACTIONS.)

In endeavoring to close the deficit gap in 1962, The Metallurgical Society Board of Directors also approved the application of royalties from books published for The Metallurgical Society by Interscience Publishers Inc. and by John Wiley & Sons Inc. exclusively toward reducing the deficit of publishing TRANSACTIONS. Also, income from the Metals Research Publications Fund will be applied to offset operating expenses of TRANSACTIONS. It is anticipated that income from these two sources, plus income from the modest subscription price increase, will assure the end of the TRANSACTIONS operating deficits.

RWS

Iron & Steel Institute Plans Autumn Meeting Nov. 29-Dec. 1

M. A. Fiennes, group managing director of Davy-Ashmore Ltd., will be nominated by the Iron and Steel Institute as its president for 1962-63 at its Autumn General Meeting which will be held November 29-December 1 in London.

A symposium on *The Future of Ironmaking in the Blast Furnace* will be the major technical subject of the meeting. Ironmaking experts from Belgium, France, US, and the UK have contributed papers for the four sessions which cover injection processes, hot-blast stoves, burden preparation, and furnace engineering.

There will also be a series of parallel scientific sessions devoted to the thermodynamics of slags, oxidation and scale, bainite, and the effect of steelmaking practice on the mechanical properties of alloy steels.

The Iron and Steel Engineers Group has organized a session on the effect of the various steelmaking processes on the energy balance of integrated iron and steelworks. This will follow the symposium on ironmaking.

Honorary Treasurer

At the meeting on July 26, H. W. A. Waring, general managing director and deputy chairman of GKN Steel Co. Ltd. was elected honorary treasurer of the Iron and Steel Institute. He succeeded Sir Julian Pode, who was elected a vice president of the Institute.

J. L. Gillson Named Crosby Lecturer At MIT For 1961-62

Joseph L. Gillson, Past President of AIME and recently retired chief geologist of E. I. du Pont de Nemours & Co., has been selected as the first William Otis Crosby Lecturer in geology at Massachusetts Institute of Technology.

The lectureship was established as a memorial to one of MIT's earliest geology graduates (Class of 1876) who, after graduation, returned to teach at MIT for more than 30 years (1875-1907). Under the terms of the bequest making possible the lectureship, scientists of note will be brought to MIT to lecture on some aspect of geology.

Dr. Gillson received B.S. and M.A. degrees from Northwestern University, and S.M. and Sc.D. degrees from MIT. He first taught at Harvard from 1920-22, and at MIT from 1922-29, meanwhile working for the US Geological Survey from 1920-28. He joined DuPont in 1928 and served the company for more than 30 years. Dr. Gillson was designated for AIME's Jackling Award and Jackling Lecture in 1957. He is also past president of the American Geological Institute (1957), and the Society of Economic Geologists (1959).

As Crosby Lecturer, Dr. Gillson will spend the school year of 1961-62 at MIT where he will deliver a two term series of lectures on his specific field of interest, industrial minerals.

Crystal Lattice Defects Conference Planned In Japan Next Year

An International Conference on Crystal Lattice Defects will be held in Kyoto, Japan, September 7-12, 1962. The conference is being organized by the Physical Society of Japan.

The aim of the conference is to obtain clearer understanding of lattice defects. Attendance will be limited to active research workers in the field and others who are preparing to enter work in this field. The language used at the conference will be English.

The conference will cover point defects in metals, semiconductors, and ionic crystals, as well as extended defects closely related to point defects. Suggested items of discussion will include electronic processes in imperfect crystals; properties of single and multiple point defects; radiation damage; and association, dissociation, and diffusion of point defects. Purely phenomenological studies will not be included, nor will work that is ambiguous from the viewpoint of lattice defects.

Chairman of the Organizing Committee is Dr. T. Fujiwara, professor of physics at Hiroshima University. All correspondence should be addressed to Lattice Defects Conference Secretariate, c/o Prof. R. R. Hasiguti, Department of Metallurgy, University of Tokyo, Bunkyo-ku, Tokyo, Japan.

Semiconductors Conference Held in Los Angeles

Following Horace Greeley's famous edict, The Metallurgical Society's annual conference on Metallurgy of Semiconductor Materials *went West* in 1961. Los Angeles' Ambassador Hotel served as headquarters from August 30 to September 1 for the third conference on this subject to be sponsored by the Institute of Metals Division's Semiconductors Committee. Providing valuable local support for this activity were members of the Metals Branch of AIME's Southern California section, which co-sponsored the conference.

Registrants were welcomed to the opening session on Wednesday morning by H. E. Bridgers of Bell Telephone Labs., Semiconductors Committee Chairman, and R. R. McNaughton of Consolidated Mining & Smelting Co. Ltd., President of AIME during 1961. The balance of the session was devoted to papers describing recent advances in materials for thermionic energy conversion. Continuing on a related theme, the topic of the afternoon session was thermoelectric energy conversion materials.

Many registrants concluded their first day at the conference by attending the annual reception and conference dinner on the evening of August 30. Serving as toastmaster was W. V. Wright, General Chairman. A thought-provoking talk was presented after dinner by Amrom Katz, of the Rand Corp., who discussed *Disarmament —Some Things to Think and Some Things to Do.*

Technical sessions on Thursday morning and afternoon were devoted to Materials and Techniques for Microelectronics.

An innovation in programming for this series of conferences was effected with the addition, this year, of a session at the end of the meeting devoted to research in progress. This session, which took place Friday morning, September 1, permitted presentation in abbreviated form of reports submitted as late as July 15 to the Conference program committee.

A total registration of more than 400 metallurgists, physicists, chemists, and others interested in semiconductor materials and applications testified to the effective planning by the Conference Committee, which included: W. V. Wright (Program), Electro-Optical Systems, Inc.; C. G. Kirkpatrick (Arrangements), Research Chemicals, div., Nuclear Corp. of America; F. P. Burns (Registration), Solid State Radiations, Inc.; J. V. Houston (Publicity), Electro Optical Systems, Inc.; and J. O. McCaldin (Treasurer), Atomics International.

Papers and discussion presented at the Los Angeles conclave will be published in The Metallurgical Society Conference Series by Interscience Publishers under the editorship of John B. Schroeder, Solid State Materials, Inc.

DCJ

Ninth Joint Engineering Management Conference Held in New York

The 9th Annual Joint Engineering Management Conference which was held at New York's Roosevelt Hotel September 14-15, offered a variety of technical papers. The conference was sponsored by ASME, AIEE, ASCE, and AIIE, with the cooperation of AIME, AIChE, and the IRE.

The four technical sessions were: Advanced Techniques and Engineering Management; Expanding Interest of Engineering; Human Values in Management; and Management of Research.

Operations Research

Featured at the first technical session on Thursday morning was a paper by Carl F. Kossack, research manager, statistics and operations research, International Business Machines, Inc., White Plains, N. Y.

In his talk, which was entitled *Statistics and Operations Research as a Tool for Engineering Managers*, Mr. Kossack said, "I would be one of the first to agree that to date we have not achieved startling success in a scientifically oriented management program. But I believe that we are on the threshold of a real breakthrough in these areas which will come about through the marriage of scientific theory and management problems by means of the electronic computer."

Two of the main areas of discussion in Mr. Kossack's paper were 1) "A brief examination of four of the basic disciplines used in statistics and operations research; and 2) A survey of existing scientific applications now available to management."

"**Simulation** is a method of studying systems," Mr. Kossack said in discussing (1). "The study of a system through the use of simulation involves the preparation of a model of the system and experimenting on it." He continued, "Happily there are two efforts that are now beginning to bear fruit that should significantly reduce the time and effort required to run a simulation. One type of effort is in the direction of a simulator complier. Through the use of such a compiler, the engineer or analyst can simply draw up the flow diagram of the system in a standard notation, and the simulation is achieved through the use of automatic coding concepts.

"The second area of computer programming aids is that of generalized models," Mr. Kossack said. "These generalized simulation models enable the engineer to stimulate his system through the specification of certain parameter values and input functions that are part of the general model."

In discussing **linear programming**, the speaker pointed out that, "Although the field of mathematical programming has expanded so that now one can include programming the additional techniques of non-linear programming, dynamic programming, and integer programming, the basic concepts are in many respects quite similar.

"Formally, the type of problem solved by linear programming involves the maximization of a linear function. . . . Numerous computer programs are available which yield the appropriate set of values that maximize the linear function."

Moving into **Statistical Decision Theory,** Mr. Kossack noted that, "The essential components in decision-making problems was first recognized by Abraham Wald in his book written in 1950 on *Statistical Decision Functions*. These consist of:

a) A set of available actions $a_1, a_2, \ldots$

b) The possible states of nature $\theta_1, \theta_2, \ldots$

c) The loss table which measures the cost of taking actions $a_1, a_2, \ldots$ respectively when the states of nature are $\theta_1, \theta_2, \ldots$ respectively.

d) The experiment yielding possible observations $x_1, x_2, \ldots$

e) The frequency responses indicating the dependency of the above observations on the state of nature.

f) The table of strategies $\gamma_1, \gamma_2, \ldots$ which indicate how one should react to any possible data.

g) And the evaluation of the table of strategies in the form of an average loss table for strategies."

"We should realize that one of the main theoretical questions is a good criterion for selecting strategies, while the practical difficulties involve the formulation of the decision problem and the estimation of the inputs. These statistical decision problems have given rise to such concepts as the minimax principle, the average regrets principle, the concept of utility, Bayes Strategies, and subjective probability," Mr. Kossack said.

In regard to the **Queuing Theory,** he continued,"One frequently encounters systems in which units arriving for service must wait before they can be serviced. If the laws governing arrivals, servicing times, and the order in which arriving units are taken into service are known, then the nature of this waiting situation can be considered mathematically under the title of Queuing Theory. There are stable situations, where the probabilities that there are units waiting at any instant remains the same as time passes; the transient case, where the probabilities have yet to settle down; and the explosive case where the waiting line increases indefinitely with time. Most of the present theory deals with the stable case with simple laws of arrival (Poisson) and exponential service times. Given a queuing situation one generally is interested in such results as the average queue length, average number of units in the system, the average waiting time of an arrival and the average time an arrival spends in the system. Mathematically, one attempts to find these quantities in terms of the parameters that describe the system."

Mr. Kossack mentioned the difficulty of adequately surveying operations research applications in a brief paper. He cited *An Annotated Bibliography of Operations Research* published by James H. Batchelor in 1959, and mentioned about 10 applications with a brief description of each.

Expressing his belief that the Operations Research approach to problems should be embedded in the operating organization of a firm or laboratory, Mr. Kossack concluded, "I do not believe that separate teams should be created and sent off to the hills to contemplate such problems, but rather that they should be made a part of the actual organization and work as closely as possible with the rest of the staff.

"In closing, I would like to note that with the advancing technologies of tele processing, automatic display, and data processing including information retrieval techniques, the time has arrived where such integrated and continuously available mathematical models will be more and more a part of the way of life of business and industry. The recent explosion of interest and application of the so-called PERT concept for project evaluation and review points the way to how much applications will continue to impact our activities. We are close to a truly integrated data processing concept as far as our capabilities are concerned. I believe management must meet this challenge by improving its capability to use this modern tool."

Other papers presented at the Thursday morning session were *PERT—A Technique for Management*, by K. M. Tebo, General Motors Corp., and *Increased Profits Through Application of Computer Technology*, by William W. Eaton, C-E-I-R, Inc.

The Thursday luncheon featured a discussion of *The Changing Personality of Today's Engineer* by I. Nevin Palley of ITT Federal Laboratories.

Other Sessions

The afternoon session, Expanding Interests of Engineering, featured

(Continued on next page)

NEW BULLETIN

A new bi-weekly bulletin of "Engineers Available" is now being published by the Engineering Societies Personnel Service, Inc. Distributed free of charge, the bulletin contains synopses of the experience of engineers who have registered with the Service and are seeking a new position.

Any employer interested in receiving the bulletin should so advise E.S.P.S. at 8 W. 40th St., New York 18, N.Y., and your name will be placed on the mailing list. Any engineer who is registered with the Service or wishes to register is entitled to a 35-word notice in the bulletin. Write to the New York office for forms. Your qualifications will be brought to the attention of employers on our mailing list without revealing your identity.

It is planned to extend the publication to the midwestern and western offices in the near future.

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Management Conference

(Continued from preceding page)

two papers: the first on *Problems of Management in Foreign Countries* by Sergio Gazitua, McGraw-Hill Publishing Co. Inc.; and the second on *The Economic Environment in Which Engineers Work,* by Carl Madden, dean of the Lehigh University College of Business Administration.

Human Values in Management was the title of the morning technical session on Friday, September 15. This session was devoted to a discussion of the human values which must be maintained in any professional group, and management's responsibility for creating an environment in which creative people can operate. Among the papers presented were *The Personal Approach in Dealing With Technical People,* by Henry L. Cox, Corn Products Co., and *Enhancing Human Values* by Francis F. Bradshaw, management consultant.

Gantt Medal

Highlight of the luncheon on Friday was the presentation of the 1961 Henry Laurence Gantt Medal to Lyndall Fownes Urwick, chairman of Urwick, Orr, & Partners Ltd., London. The citation accompanying the medal read, "Recognized authority on management with unusual ability in the field of organization whose pronouncements have world wide recognition; devout apostle of the professional stature of the manager; creative leader in adult education for managers; constructive and generous contributor to the world community through his profound works in management in both government and industry."

The Gantt Medal is awarded annually by the American Management Association and the American Society of Mechanical Engineers for distinguished achievement in management as a service to the community. It was established in 1929 honoring Henry Laurence Gantt, distinguished management engineer, industrial leader, and humanitarian.

Management of Research

The afternoon session, Management of Research was devoted to the problems of managing the creative efforts of high-level engineers and scientists. In a paper entitled *Managing for Creativity in Engineers,* Harcourt C. Vernon of E. I. du Pont de Nemours & Co., cited the four basic laws of managing for creativity: 1) Avoid turmoil by leaving a man with his assignment long enough for him to achieve an identifiable accomplishment.

2) Surround his effort with the minimum of controls so it is his own responsibility to achieve his results.

3) Insure that all decisions and policies that affect him even remotely are convincingly shown to be rational, sensible, and constructive.

4) Provide as many means as practicable to demonstrate the importance to the overall effort of each person's personal effort."

Mr. Vernon concluded, "To these I add the first and overriding law: Listen to and give real consideration to the ideas of each person."

The final paper was *Management of Research and Development Personnel in an Industrial Laboratory* by R. B. Mears, U.S. Steel Corp. Mr. Mears declared, "The manager's first problem is to determine what type or combination of benefits his company expects for the money it invests in research. . . . Once the aims are delineated, the manager's job is to organize the research effort so as to achieve these aims as rapidly and economically as possible.

"It has also been stated that research management's most important function is that of selecting and retaining the right type of technical personnel," Mr. Mears, stated, adding that, "knowing what the *right* type is for any specific opening is extremely difficult.

"A wide variety of types of people strengthens the research organization," Mr. Mears declared, "especially if management can create the (true) impression that all of these types are equally valuable to the total research effort."

Mr. Mears continued, ". . . the actual reason for the existence of the laboratory is to provide the body that supports it with the technical information needed to survive.

"Thus the whole edifice collapses if the laboratory does not develop this necessary information, since the sponsoring body will no longer be able to supply the funds necessary to keep the laboratory going.

"Therefore the prime requisite of research management is to make certain that the laboratory develops the technical information required by the sponsoring company and communicates this information in a usable form to the appropriate departments of that company."

Mr. Mears concluded, "Research personnel derive a tremendous amount of satisfaction when they realize that their efforts are an essential factor in assisting their company to survive. Instead of being allowed to stagnate in the backwater they come to realize that they are a vital part of the corporate team. Laboratory management must constantly strive to assist the laboratory staff in attaining this feeling of the importance and urgency of their efforts toward the corporate welfare."

a new book

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The Metallurgical Society of AIME

Extractive and Physical Metallurgy of Plutonium and its Alloys

The Proceedings of a Technical Symposium sponsored by the Nuclear Metallurgy Committee of the Institute of Metals Division, and the Titanium, Uranium, and Uncommon Metals Committee of the Extractive Metallurgy Division, The Metallurgical Society of AIME. San Francisco, February 16-17, 1959.

Edited by W. D. WILKINSON, Argonne National Laboratory

The addition to these Proceedings of an introductory chapter on the metallurgy of plutonium and of an extensive annotated bibliography has made this volume of even greater value to metallurgists working in this particularly important field. Mr. Wilkinson both edited the Proceedings and provided the new material.

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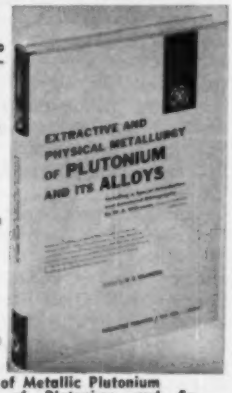
Introduction to Plutonium Metallurgy

EXTRACTIVE METALLURGY

- Alternative Routes for the Conversion of Plutonium Salts to Metal and Their Recovery Problems
- Calcium Reduction of Plutonium Halides to Metal
- Preparation of Metallic Plutonium
- Distribution of Plutonium and Selected Impurity Elements between Nitrate Solutions and Tri-n-butyl Phosphate
- The Preparation of Plutonium Halides for Fused Salt Studies
- Removal of Fission Product Elements from Plutonium by Liquidation

PHYSICAL METALLURGY

- Some Principles of the Alloying Behavior of Plutonium
- The Plutonium-Cerium Diagram
- Plutonium-Zinc Phase Diagram
- Metallography of Alpha Plutonium
- The Etching of Plutonium and Its Alloys by Cathodic Bombardment
- A Study of the Transformation Kinetics of Alpha, Beta, and Gamma Plutonium
- Some Experiments in Zone Refining Plutonium
- Behavior of Some Delta-Satilized Plutonium Alloys at High Pressure
- Annotated Bibliography



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AROUND THE SECTIONS

The speakers at the September 7 meeting of the Southeast section, AIME, were (l to r) James Nicol, chairman, Southeast section; B. W. Worthington, C. B. Thompson, and Thomas B. Ban, panelists for the evening; and Monro B. Lanier, member of the Southeast section, who introduced the program.

Southeast section, AIME, held its first meeting in the fall series on September 7 in Birmingham, Ala.

The topic of the evening discussion was *Direct Reduction of Iron Ore Without the Use of Blast Furnace.* A well-organized presentation of the process was given jointly by B. W. Worthington, retired director of research at McWane Cast Iron Pipe Co., and Thomas B. Ban and C. B. Thompson, both of McDowell Inc., Cleveland, Ohio. At the conclusion of the formal program, a question and answer session was conducted by the panelists.

The meeting established an attendance record with 161 people.

Pittsburgh section, AIME, held its Annual Smoker at the Penn-Sheraton Hotel on October 6. The smoker was preceded by a panel discussion on *The Professional Engineer.* Panelists Arthur Sterling, Eugene L. Recchion, and David Figgins—all members of the Pennsylvania Society of Professional Engineers—discussed salaries, ethics, professional status, and unity in the engineering profession.

The smoker featured songs by Mary Margaret Briney. Members attending wore derbies, mustaches, and sleeve garters, reminiscent of the 1890's. Beer and do-it-yourself sandwiches were served.

Buffalo section, National Open Hearth Steel Committee, will hold its twelfth annual fall meeting on November 14 at the Royal Connaught Hotel, Hamilton, Ont., Canada.

Following registration for the meeting there will be a plant tour of the No. 3 Open Hearth Shop of Steel Co. of Canada Ltd., at Hamilton, Ont.

A luncheon, courtesy of the suppliers' committee, will be held in the hotel's Crystal Ballroom. The afternoon will be devoted to technical sessions in the Sheraton Room.

The Buffalo section is sponsoring a local contest for papers which will ultimately be submitted for the McKune Award. All entries will be reviewed by a special committee of open hearth superintendents in the section, and the best entry will be read during the technical session.

Other papers to be presented include *Operating Safety* by Harry Hickey, Bethlehem Steel Co.; a paper on *Scrap Preparation* and a film, *Calderon Charger,* presented by D. Celani, Republic Steel Corp.; and *Control of Splash of Top Pour Ingots* by George Newton, Steel Co. of Canada Ltd., and William McShane, Bethlehem Steel Co. Also, *Design and Function of Industrial Precipitators* by Lee Dickinson, Bethlehem Steel, and *Economics of Basic Roofs on Open Hearth Furnaces* by Charles Jewart, also Bethlehem.

Chicago section, AIME, in cooperation with the Refractory Metals Committee of The Metallurgical Society, will sponsor a Refractory Metal Symposium which will be held at the Morrison Hotel in Chicago, April 12-13, 1962.

Group To Certify Engineering Technicians Formed By National Society of Professional Engineers

An Institute for the Certification of Engineering Technicians has been organized by the National Society of Professional Engineers. The purpose of the Institute is: 1) To elevate the performance standards of engineering technicians as an important part of the engineering team; 2) Determine the competence of engineering technicians through investigations and examinations to test the qualifications of voluntary candidates for certificates to be issued by the Institute; and 3) Grant and issue certificates to engineering technicians who voluntarily apply therefor and maintain a registry of holders of such certificates.

The Institute is an examining and certifying body *only* which will determine qualifications for three classes of technician upon voluntary submission of credentials by a person seeking such recognition. It is not another technical society, nor is it a class of membership in NSPE.

The definition of an engineering technician adopted in 1953 by the Engineers Council for Professional Development indicates the nature and scope of experience to be judged.

"An engineering technician is one who can carry out in a responsible manner either proven techniques which are common knowledge among those who are technically expert in this branch of engineering, or those especially prescribed by professional engineers. Under general professional engineering direction, or following established engineering techniques, he shall be capable of carrying out duties which may comprise: working on design and development of engineering plan; draftsmanship; the erection and commissioning of engineering equipment or structures; estimating; inspection, and testing engineering equipment; use of surveying instruments; maintaining engineering machinery or engineering services and locating faults; operating, maintaining, and repairing engineering plant; or activities connected with research and development, sales engineering and representation, servicing and testing of materials and components, advising consumers, and training and education.

"In carrying out many of these duties, the competent supervision of the work of skilled craftsmen will be necessary. The techniques employed demand acquired experience and knowledge of a particular branch of engineering, combined with the ability to work out the details of a job in the light of a well-established practice.

"An engineering technician, therefore, requires a background sufficient to enable him to understand the reasons and purposes of the operations for which he is responsible."

Persons engaged in the practice of engineering are excluded from consideration since matters in the professional realm fall under the jurisdiction of the various state boards of engineering examiners. To make certain that no confusion exists each certificate shall carry a statement to the effect that such certification does not constitute a license to practice engineering.

Bylaw summary

The bylaws governing the certification of engineering technicians provide that the Institute shall be governed by a board of trustees composed of four registered professional engineers and four senior engineering technicians certified by the Institute.

The professional engineer members of the board shall be appointed by the president of the National Society of Professional Engineers, subject to approval by its board of directors.

Members of the board of trustees will serve without pay, but may be reimbursed for expenses entailed in the execution of their duties.

The board of trustees will have the authority to make all proper rules and regulations for the operation of the Institute including, but not limited to, those listed below.

1) Establishing of committees and appointments thereto.

2) Designation of appropriate grades or classes for certification of engineering technicians.

3) Preparation of examinations and designation of evaluation procedures for various grades or classes of engineering technicians.

4) Appointment of persons or organizations to administer examinations, either written or oral, and determination of payment for such services.

5) Preparation and issuance of certificates for appropriate grades or classes of engineering technicians.

6) Determination of application and certificate fees for each grade or class of engineering technicians.

7) Determination of times and places for examinations or interviews.

8) The revocation or suspension of certificates previously issued upon grounds of fraud or misrepresentation by the person certified in his submission of supporting data for consideration in applying for a certificate.

9) Determination of an annual renewal fee from certified engineering technicians.

The Institute will have a chairman, a vice chairman, and a secretary-treasurer. The chairman and vice chairman shall be elected by the members of the board of trustees from among its number. The secretary-treasurer will be appointed by the board.

The Institute's board of trustees will appoint an executive secretary who will be a member ex-officio of the board, but will not vote or hold office while serving in this capacity. He will receive compensation, the amount of which shall be determined by the board.

The Institute has established the following grades and classes for certification as engineering technicians:

a) Engineering Technician Trainee —A person who is acquiring training and experience to qualify for the grade of engineering technician. He must have worked at least two years during which time he shall have demonstrated elementary technical ability as indicated by endorsement of a professional engineer or equivalent who has personal knowledge of the applicant.

b) Engineering Technician—A person who, (1) in addition to possessing the qualifications stated in subsection **a** above, has demonstrated technical knowledge at the level of a graduate from an Engineers' Council for Professional Development accredited program leading to the Associate Degree in some field of engineering technology, or (2) he shall be a graduate of an ECPD accredited program. He must have at least five years experience under the direction of a professional engineer or equivalent. Evidence of experience shall be supported by the endorsement of a professional engineer or equivalent who has personal knowledge of the education and experience of the applicant. In no case shall a person become an engineering technician who is not at least 25 years of age at the time of the application for that grade of membership.

c) Senior Engineering Technician —A person who, in addition to posessing the qualifications stated in subsections **a** and **b** above, has had at least ten years of technical experience of a high-level detailed technical nature under the direction of a professional engineer or equivalent. Evidence of a satisfactory record shall consist in endorsement by a professional engineer or equivalent who has personal knowledge of the education and experience of the applicant. In no case shall a person become a Senior Engineering Technician who is not at least 35 years of age at the time of application for that grade of membership.

MEMBERSHIP

Proposed for Membership
Metallurgical Society of AIME

Total AIME members on Sept. 30, 1961, was 35,481; in addition 2,140 Student Members were enrolled.

ADMISSIONS COMMITTEE

W. L. Brytczuk, Chairman; S. C. Carapella, Jr.; J. W. Hanley; T. D. Jones; H. C. Larson; Harold Margolin; Shadburn Marshall.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

Beck, Roman F., Cleveland, Ohio
Bestland, Roy J., Riviera Beach, Fla.
Biretta, Vitti J., Dallas, Tex.
Bourland, Gordon W., Arlington, Tex.
Brien, Robert E., Kearny, N. J.
Bronson, Horace W., New York, N. Y.
Buckingham, Edward L., Arlington, Tex.
Condon, Maurice J., Dallas, Tex.
Conklin, Alfred N., Welland, Ont., Canada
Dudley, Edward F. Jr., Oak Park, Ill.
Eldridge, Jerome M., Monroeville, Pa.
Gerard, Gary, Permanente, Calif.
Haefling, James F., Garland, Tex.
Krenkel, Donald C., Kansas City, Mo.
Miller, Arnold, Fullerton, Calif.
Pitsenberger, John W., Washington, D. C.

Associate Members

Hicks, Robert G., Beaverton, Ore.
Hamilton, Charles B., Portland, Ore.
Kayser, Manfredo, Buenos Aires, Argentina

Junior Members

Alter, Donald J., Forest Hills, N. Y.
Aul, Frank W., Pittsburgh, Pa.
Beasley, Jack M., Grand Prairie, Tex.
Cosgrove, George J., Pittsburgh, Pa.

CHANGE OF STATUS

Associate to Member

Liberto, Vincent J., Metairie, La.

Junior to Member

Wriedt, Henry A., Monroeville, Pa.

Student to Junior

DeBall, Donald J., Chicago, Ill.

SPECIAL REINSTATEMENT

To Member

Dunn, Edward J., Thomaston, Conn.

To Associate

Perfect, Fred H., Wyomissing, Pa.

NEW STUDENT MEMBERS

Case Institute of Technology
Nelson, Carl W.,

Missouri School of Mines
Kessler, Sergio E.

University of Oklahoma
Kim, Jang H.

University of Pittsburgh
Adamson, Daniel H.

Stanford University
Rudee, Mervyn L.

NECROLOGY

Year Elected	Name	Date of Death
1959	Anderson, O. Jalmer	Aug. 20, 1961
1940	Cole, J. Gordon	July 15, 1961
1956	Hamberger, K. L.	June 31, 1961
1908	Jackson, George R. (Legion of Honor)	Aug. 29, 1961
1957	Lynn, A. B., Jr.	June 17, 1961
1931	Mutz, Herman J.	Apr. 6, 1961
1920	Shinkle, V. G.	Aug. 7, 1961

Argentine Group Offers Course In Nuclear Metallurgy

The Comision Nacional de Energia Atomica of Argentina, in cooperation with the Inter-American Nuclear Energy Commission of the Organization of American States, will offer a course in Nuclear Metallurgy from March through December 1962. The course will be held at the Comision's laboratories in Buenos Aires.

The course will begin March 21, and will continue through December 21. It will be limited to 14 students, all of them on fellowships. Special fellowships will be made for successful US applicants. The scholars will attend classes in theory and practice presented by Argentine and foreign university professors and research investigators of the National Atomic Energy Commission.

Candidates for participation as students in the course should be citizens of one of the American Republics; they should be university graduates in metallurgy, chemistry, physics, or one of the branches in engineering; and they must demonstrate fluency in Spanish.

The National Atomic Energy Commission will provide modern laboratories consisting of facilities for welding and thermal treatment, mechanical deformation, and powder metallurgy, as well as a central laboratory for basic research equipped with optical microscopes, a vacuum dilatometer, microhardness tester, and an X-ray unit.

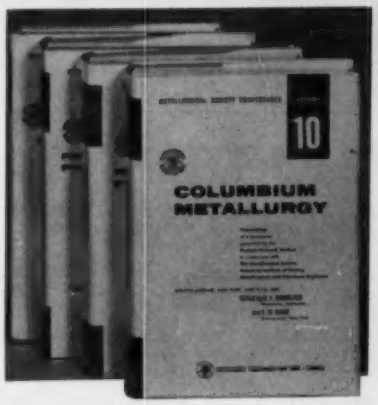
US applicants may obtain further information related to the first Pan American Course in Nuclear Metallurgy by writing to Dr. Jesse D. Perkinson, Director; Division of Science Development; Pan American Union; Washington 6, D. C. Applications should be submitted by December 1.

Iron & Steel Engineers Elect Officers for '62

Harry L. Jenter of U.S. Steel Corp. has been elected president of the Association of Iron and Steel Engineers for 1962. Announcement of his election was made at the AISE Annual Convention which was recently held in Pittsburgh.

Other officers elected by the society are C. W. Bruce, Republic Steel Corp., first vice president; H. R. Knust, Bethlehem Steel Co., second vice president; N. C. Michels, U.S. Steel Corp., treasurer; M. B. Antrim, Lukens Steel Co., secretary; and J. L. Laidlaw, Algoma Steel Corp. Ltd., director-at-large.

Terms of office for all men will begin Jan. 1, 1962.



FOUR NEW VOLUMES METALLURGICAL SOCIETY CONFERENCES

VOLUME **10** — **Columbium Metallurgy**

Proceedings of the Technical Conference sponsored by the Hudson-Mohawk Section, and The Metallurgical Society of AIME. **Belton Landing, New York, June 9-10, 1960**

Edited by D. L. DOUGLASS and F. W. KUNZ
764 pages $26.00

VOLUME **11** — **Refractory Metals and Alloys**

Proceedings of the Technical Conference sponsored by the Refractory Metals Committee of the Institute of Metals Division, The Metallurgical Society, and the Detroit Section of AIME. **Detroit, May 25-26, 1960**

Edited by M. SEMCHYSHEN and J. J. HARWOOD
635 pages $22.00

VOLUME **12** — **Metallurgy of Elemental and Compound Semiconductors**

Proceedings of the Technical Conference sponsored by the Semiconductors Committee of the Institute of Metals Division, The Metallurgical Society, and the Boston Section of AIME. **Boston, August 29-31, 1960.**

Edited by RALPH O. GRUBEL
506 pages $13.00

VOLUME **13** — **Bar and Allied Products**

Proceedings of the Technical Conference sponsored by the Mechanical Working Committee, Iron and Steel Division, The Metallurgical Society, and the Pittsburgh Section of AIME. **Pittsburgh, January 18, 1961**

Edited by E. W. EARHART and JOHN F. GRIFFIN
Approx. 150 pages in press

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Coming Events

Nov. 3, 1961, Pittsburgh Section, 16th Off-the-Record Meeting, Penn-Sheraton Hotel, Pittsburgh, Pa.

Nov. 13-16, 1961, Seventh Annual Conference on Magnetism and Magnetic Materials, Hotel Westward Ho, Phoenix, Ariz.

Nov. 14, 1961, Buffalo Section, NOHC, 12th Annual Meeting, Royal Connaught Hotel, Hamilton, Ont., Canada.

Nov. 29-Dec. 1, 1961, Iron and Steel Institute (U.K.) Fall General Meeting on Future of Ironmaking in the Blast Furnace, London.

Nov. 29-Dec. 3, 1961, Argentine Atomic Energy Commission, First Colloquium in Powder Metallurgy, Buenos Aires, Argentina.

Dec. 4, 1961, Annual Meeting, Arizona Section, AIME, Pioneer Hotel, Tucson, Ariz.

Dec. 4-5, 1961, New York University, Conference on Beryllium Metallurgy, Washington Square Center, NYU, New York.

Dec. 6-8, 1961, 19th Electric Furnace Conference, Penn-Sheraton Hotel, Pittsburgh, Pa.

Jan. 9-11, 1962, Eighth National Symposium on Reliability and Quality Control, Statler Hilton Hotel, Washington, D. C.

Jan. 15-17, 1962, Minnesota Section, AIME, Annual Meeting held jointly with 23rd Annual Mining Symposium, Hotel Duluth, Duluth, Minn.

Jan. 17, 1962, AIME Mechanical Working Conference, Pick-Congress Hotel, Chicago.

Feb. 18-22, 1962, AIME Annual Meeting, New York, N. Y.

Apr. 9-11, 1962, National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Sheraton-Cadillac Hotel, Detroit.

Apr. 9-13, 1962, American Welding Society, 43rd Annual Convention and Welding Exposition, Sheraton Cleveland Hotel, Cleveland, Ohio.

Apr. 12-13, 1962, Chicago section, AIME, in cooperation with IMD Refractory Metals Committee, Refractory Metal Symposium, Morrison Hotel, Chicago, Ill.

Apr. 12-14, 1962, AIME Pacific Southwest Minerals Industry Conference, Palace Hotel, San Francisco, Calif.

April 26-28, 1962, AIME Pacific Northwest Metals and Minerals Conference, Ben Franklin Hotel, Seattle, Wash.

May 2-3, 1962, Iron & Steel Institute (U.K.), Annual General Meeting, London.

May 7-8, 1962, Institute of Metals (U.K.), Symposium on Sintered Low-Alloy Steel Engineering Components, London.

May 7-11, 1962, American Foundrymen's Society, Foundry Show, Cobo Hall, Detroit, Mich.

July 2-6, 1962, Iron & Steel Institute (U.K.), Special Meeting in Dusseldorf, Germany, by invitation of the Verein deutscher Eisenhuttenleute.

Aug. 27-29, 1962, AIME 4th Annual Technical Conference on Semiconductors, Benjamin Franklin Hotel, Philadelphia, Pa.

Sept. 19-21, 1962, AIME Rocky Mountain Minerals Conference, Salt Lake City, Utah.

Oct. 20-26, 1962, Sixth World Power Conference, Melbourne, Australia.

Oct. 28-Nov. 1, 1962, Fall Meeting of The Metallurgical Society of AIME, New York City.

Nov. 28-29, 1962, Iron & Steel Institute (U.K.), Autumn General Meeting, London.

OBITUARIES

John R. Freeman

John R. Freeman, retired vice president in charge of research at the Anaconda-American Brass Co. died September 3 at his home in Middlebury, Conn. He was 65 years old.

Mr. Freeman retired as vice president in September 1960, but continued to serve as metallurgical consultant to the Anaconda Sales Co., and represented Anaconda as its technical representative in the Copper Products Development Assn.

A graduate of Massachusetts Institute of Technology, Mr. Freeman was with the National Bureau of Standards from 1916-1930.

He is survived by his wife, a son, and two daughters.

Prof. C. W. Dannatt

Prof. Cecil William Dannatt died on April 9 at the age of 68, three years after his retirement from the Royal School of Mines. His association with the school dated from 1910, when he entered as a student of metallurgy, and was interrupted only by a period of eight years during and following the first World War. After spending four years in the army, he spent two years in Egypt as assistant director of a technical section of the Ministry of the Interior, and about two years in Trinidad on geological and surveying work for an oil company.

He returned to the Royal School of Mines in 1923 and joined the teaching staff of the Metallurgy Department. He became assistant professor and reader in 1937. In 1945 he was appointed head of the department and professor of metallurgy. He retired from the university in 1957. The title of professor emeritus was conferred on him in 1960.

William K. Sproule

William Kelvin Sproule, consulting metallurgist with the Development and Research Div., International Nickel Co. Inc., died in New York on August 8, after a long illness. He was 48 years old

A native of Montreal, Que., Mr. Sproule received a B. E. degree in metallurgy from McGill University in 1936, and the M.Sc. in 1937. He joined International Nickel the same year.

Mr. Sproule had been a member of AIME since 1936, and was the author of the paper, *Treatment of Nickel-Copper Matte* which appeared in JOURNAL OF METALS March 1960.

Mr. Sproule lived with his family in Summit, N. J. He is survived by his wife and three children.

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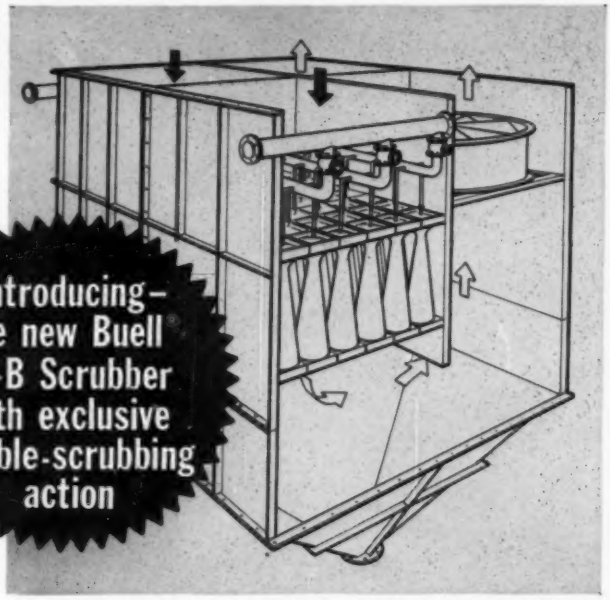

introducing– the new Buell W-B Scrubber with exclusive double-scrubbing action

Service-proved in applications around the world, the new Buell W-B Scrubber is now available for sub-micron dust removal jobs in this country. This newest multi-venturi wet collector removes over 99% of dust as small as 0.05 microns. Licensed under the famous Waagner-Biro patents, the new Buell W-B Scrubber offers several distinct benefits over other wet collectors. The most important are discussed below. ■ There are other operating advantages, too, including low water requirements, and case-hardened venturi throat to resist erosion. But why not check into the Buell W-B Scrubber for your own application? For details, write Buell Engineering Co., Inc., Dept.K-70123 William St., New York 38, N. Y.

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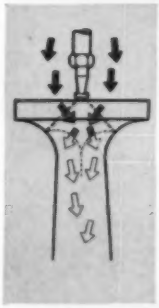
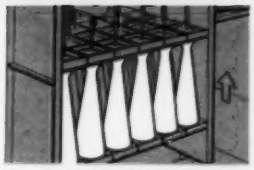


double-scrubbing action Exclusive! Water is introduced ahead of the venturi, which forms two distinct cones for gas to pass through

typical iron and steel industry uses oxygen converter dust—open hearth dust—ferromanganese fumes and ferrosilicon dust from electric furnaces—iron, coke and silica dust from gray iron cupolas—iron, carbon dust from rotary kilns—Taconite ore dust from crushing and screening.

low power This special design achieves the desired efficiencies with low pressure drops; thus, requires minimum power ■ **high efficiency** The Buell W-B Scrubber offers efficiencies for given conditions higher than any similar system.



any capacity The new Buell W-B Scrubber is made up of multiple venturi tubes—each a standard, readily-stocked item. Capacity for your application is arranged simply by designing for the proper number of venturi tubes.

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BUELL W-B SCRUBBERS FOR SHARON STEEL The first Buell W-B Scrubbers on this continent have been ordered by Sharon Steel Company, to serve North America's first STORA KALDO steelmaking facility. Engineers for this pioneering installation are Dravo Corporation.

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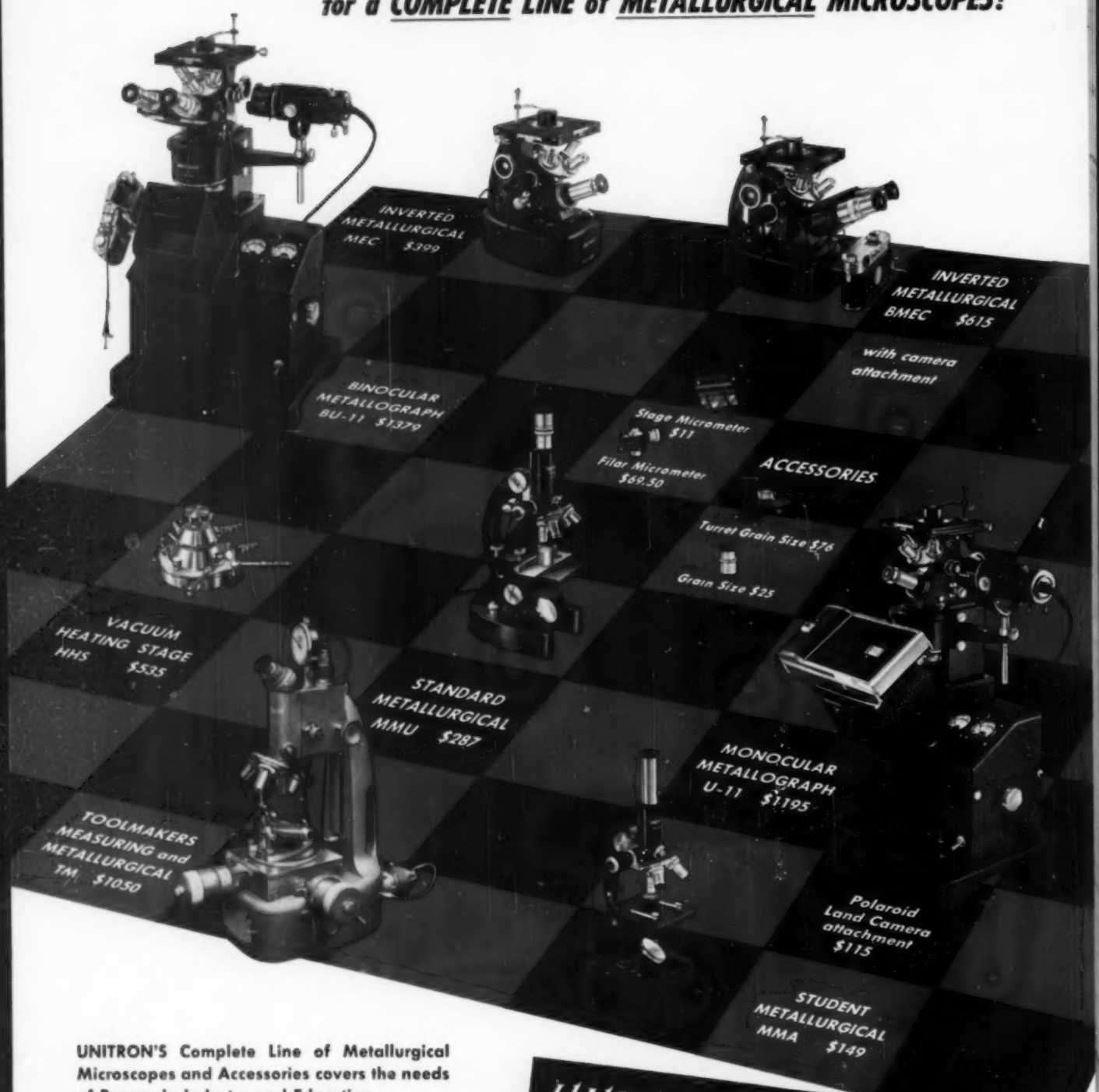

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